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Forensic Cranio Facial Reconstruction Using Cone Beam Computed Tomography Current Concepts and Future Research

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Abstract

There is indispensable need of adding Cranio Facial Reconstruction (CFR) database using Cone Beam Computed Tomography (CBCT) of various populations for forensic facial reconstruction (FFR) purposes. The aim of this review paper is to give an exhaustive and critical review of the advantages of using CBCT over other 3D reconstruction techniques. Conferring facial soft tissue thickness (FSTT) population studies database of varied population till date defined within a common framework of facial identification. Extensive online searches were conducted and with all kinds of evidence exists an overview is provided. Further, the paper will also discuss the deficiencies in research database of FFR with CBCT in various populations and focus to create awareness of future requirements. Finally, we conclude this review by suggesting future directions of theneed to collect as much CFR data as possible using CBCT with set norms among different populations and subsequently performing validation to increase the practical relevance of CFR methods in crime-scene investigations.

Keywords: CBCT; Soft Tissue Thickness; Forensic Craniofacial Reconstruction.

Introduction

One of the most importantroles of the forensic odontologistis to do identification of the deceased individuals. In circumstances of natural or manmade disasters, fire burns, terror attack, accidents related to aviation, railways or road. The identification is crucialnot only for humanitarian causes but also for religious and judicial reasons [1]. Even though DNA investigation for human remain identification is most acceptable, many cases still exist in which the decreased remains are unidentified. Therefore, 3D facial reconstruction may be used as a helping tool to decrease the number of individuals that remain unidentified.

Forensic Craniofacial Reconstruction (CFR) is an investigative technique established on scientific standards and artistic skill, used to elicit recognition of a deceased person by reconstructing the most likely face establishing from the skull. It is also known as ''forensic facial approximation" (FFA) [2]. A crucial element in CFR methods are approximations of facial soft tissue depths (TD) at specific points (landmarks) on the skull constructed on averages from databases of TD recordings. These databases differ not the only method of extraction, the condition of the body, number and position of landmarks, but also on the population studied, and sub-categorization of the data [3]. It'simportant to comprehend that CFR is not a technique of identification, but means of recognition. This method can help police and forensic experts tomake a list of most probable names from which the deceased may be identified by DNA investigation, dental record examination, or other accepted methods of identification [4].

The reconstruction techniques include two-dimensional (2D), three dimensional (3D) and manual or computer-based techniques. 3D Cone beam computed tomography (CBCT)techniqueis already

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well establishedfor the imaging of the maxillofa-cial region. Its applicability, by measuring the soft tissue thickness for peri-implant graft procedure, sites for the place-ment of temporary anchorage devices, facial asymmetry analysis and facial reconstruction to mention some have previously been explored by researchers [5].

The aim of this review is analyzingCBCT advancement over other 3D forensic facial reconstruction techniques.Conferring Facial Soft Tissue Thickness (FSTT) population studies database of varied population till date, defined within a common framework of facial identification. Discussing the deficiencies in research database of forensic craniofacial reconstruction (CFR) with CBCT in various populations. Focusing to create awareness of future requirements and practical issues related to CBCT CFR, without going into technical details. The review clearly articulates the justification to establish archival, reference databases to compare and evaluate different strategies.

Material & Methods

Extensive online searches were conducted in various databases (PubMed, Cochrane Library and Google Scholar), dated between 1948 to 2017and with all kinds of evidence exists an overview is provided.

Review of Literature

The main purpose of craniofacial approximation is to refabricateresemblance of facial appearance from an anonymous skull using the relationship between FSTT and the skull [6,7]. CFR techniques can be classified into three categories: the anatomical Russian method, the anthropometrical American method, and the combination Manchester method [8,9,10]. There are two basic methods of modelling faces, morphoscopic method [11,12] using an anatomical approach of reconstructing the musculature, fat and skin and morphometric method [13] using average facial soft tissue depth measurements that have been gathered by various researchers (Figure1).

For approximate facial recon-struction of the human face, it is necessary to know the average FSTT of particular sites on the face. This requires establishing a database of TD related to age, sex, race, ethnicity [11], skull shape [12], nutritional status [7,16] and body mass index [17] (Figure 2).

The precision of a forensic reconstruction can be evaluated by means of a face pool. Face pool analysis compares the reconstructed face to a group of faces that comprises the target of the same gender, ethnic group, and approximate age [18]. Many imagining techniques like magnetic resonance imaging (MRI)

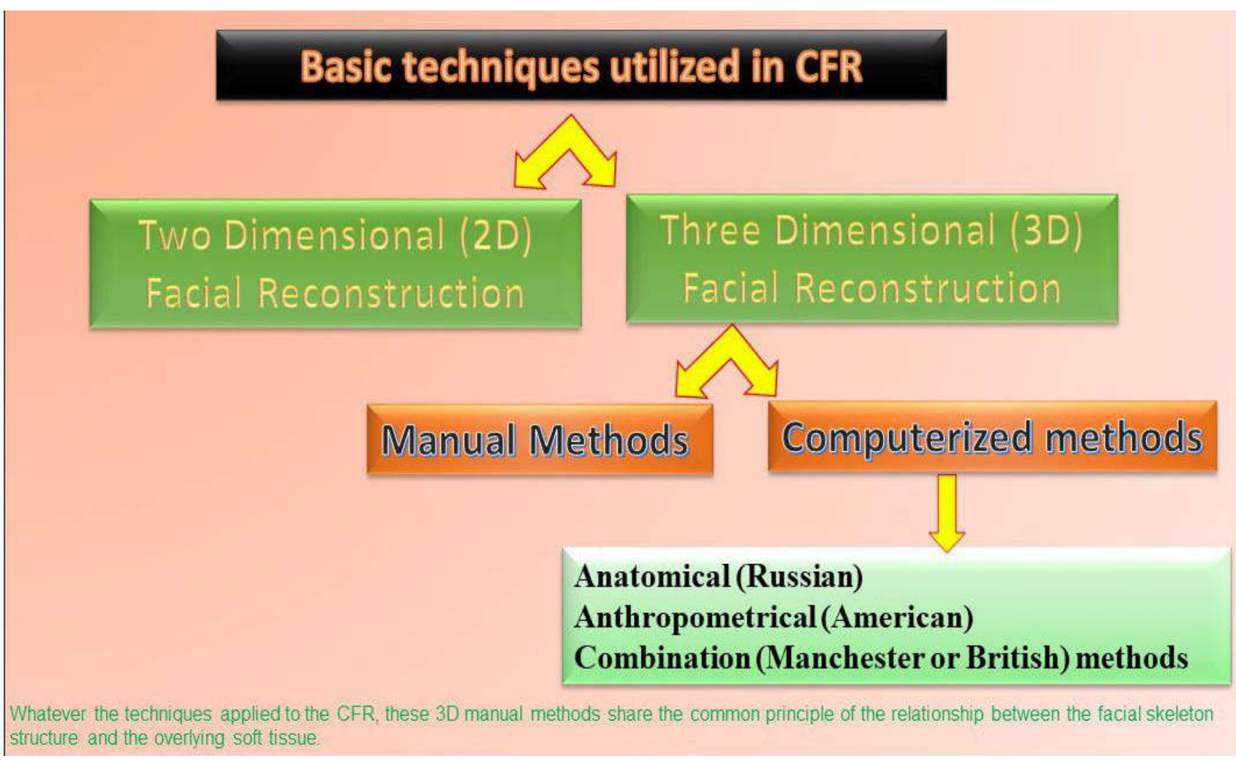

Fig. 1: Techniques and methods of CFR

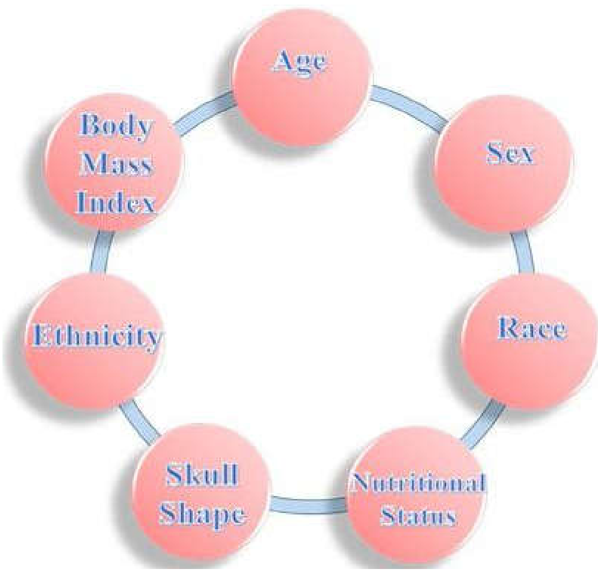

Fig. 2: Requirement to establish TD database

[19], computed tomography (CT) [20] ultrasound (US) [7] and cephalometric radiographs [21] have been used till date to study the facial soft tissue thickness. It's been shown recently that CBCT images of the face are a much reliable method of measuring the soft tissue thickness in the facial region and give a good representation of the FSTT [11].

With advancement in 3D imaging techniques, it is possible now to comparethe distances between the 3D surfaces of the forensic reconstruction with the 3Dsurface of the target soft tissue for quantitative assessment (Figure 3) [18]. The principal of CBCT is based on the usage of cone beam acquisition geometry and flat panel detection (FPD) since they provide comparatively low dose imaging with high isotropic spatial resolution acquired with a single gantry revolution. Maximum CBCT units for maxillofacial analysis use an image intensifier tube/charge coupled device (IIT/CCD). A flat panel imager (FPI) is more advanced version as it consists of a cesium iodide scintillator applied to a thin film transistor made of amorphous silicon. Images produced with an IIT usually result in more noise than images from an FPI and also need to be pre-processed to reduce geometric distortions inherent in the detector configuration [22]. It has a number of advantages over other methods of soft tissue thickness measurement like increased speed of data collection, less invasiveness and the ability to obtain a 3D archive of the subject's facial morphology. CBCT visualizes high-contrast insufficient quality with a remarkably

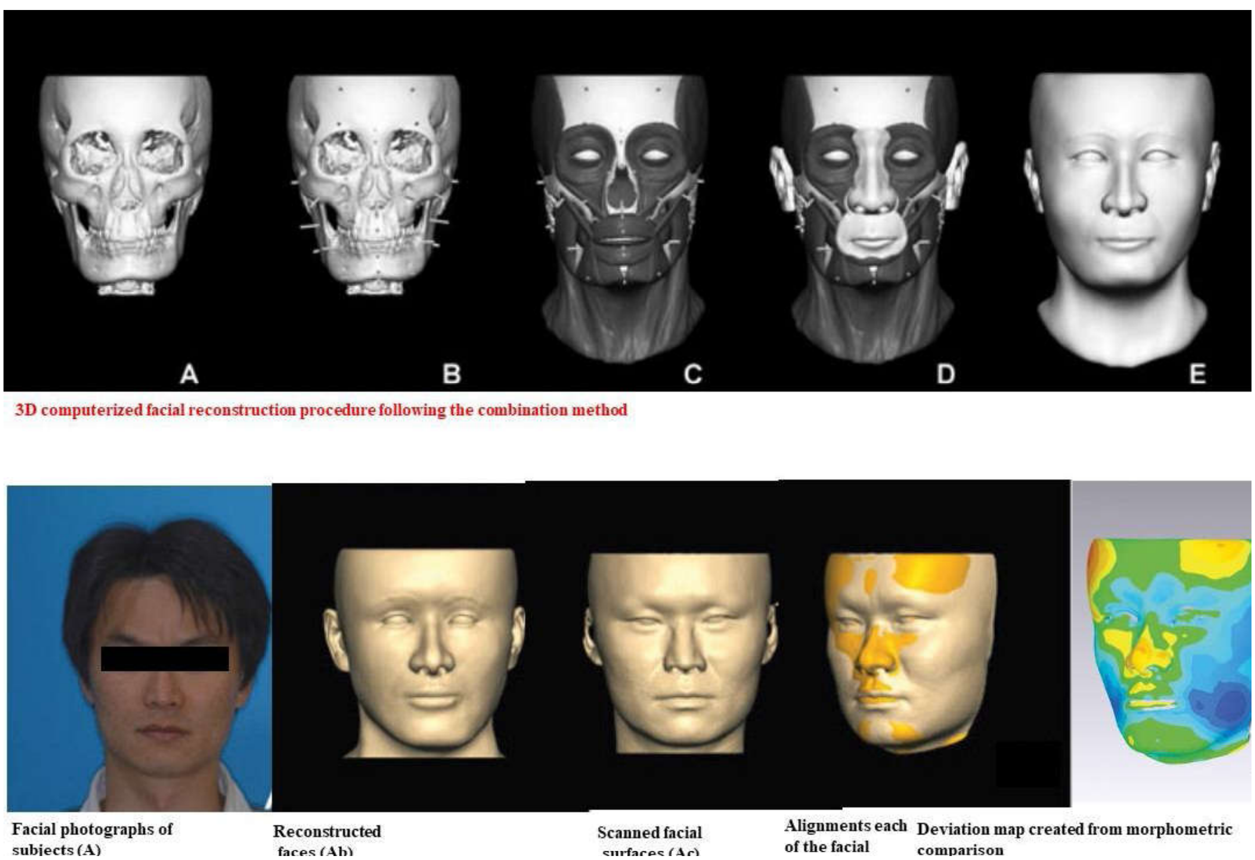

Fig. 3: 3D computerized facial reconstruction procedure following the combination method[8]

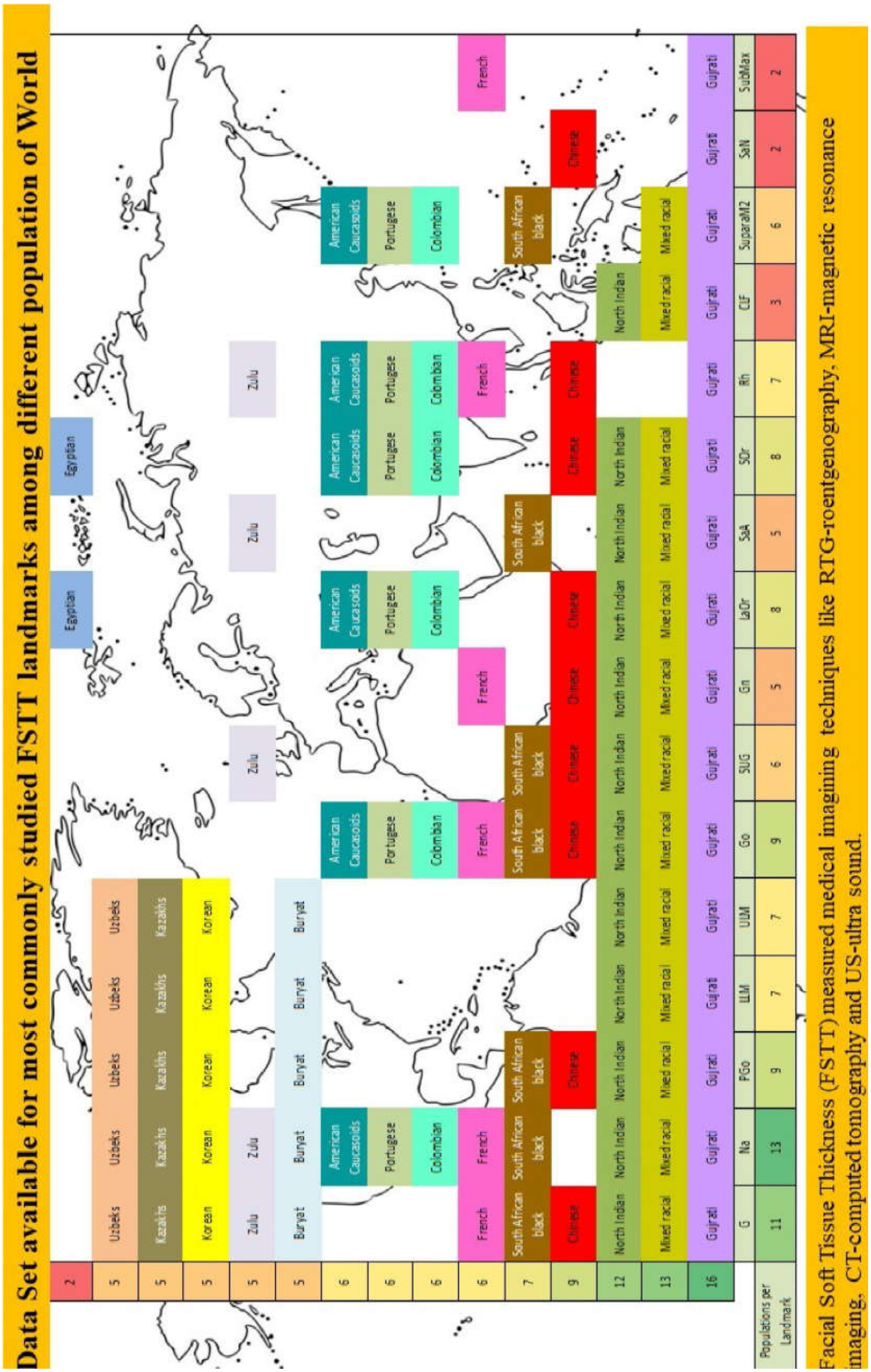

Fig. 4: Dataset available for most commonly studied FSTT landmarks among different population of world

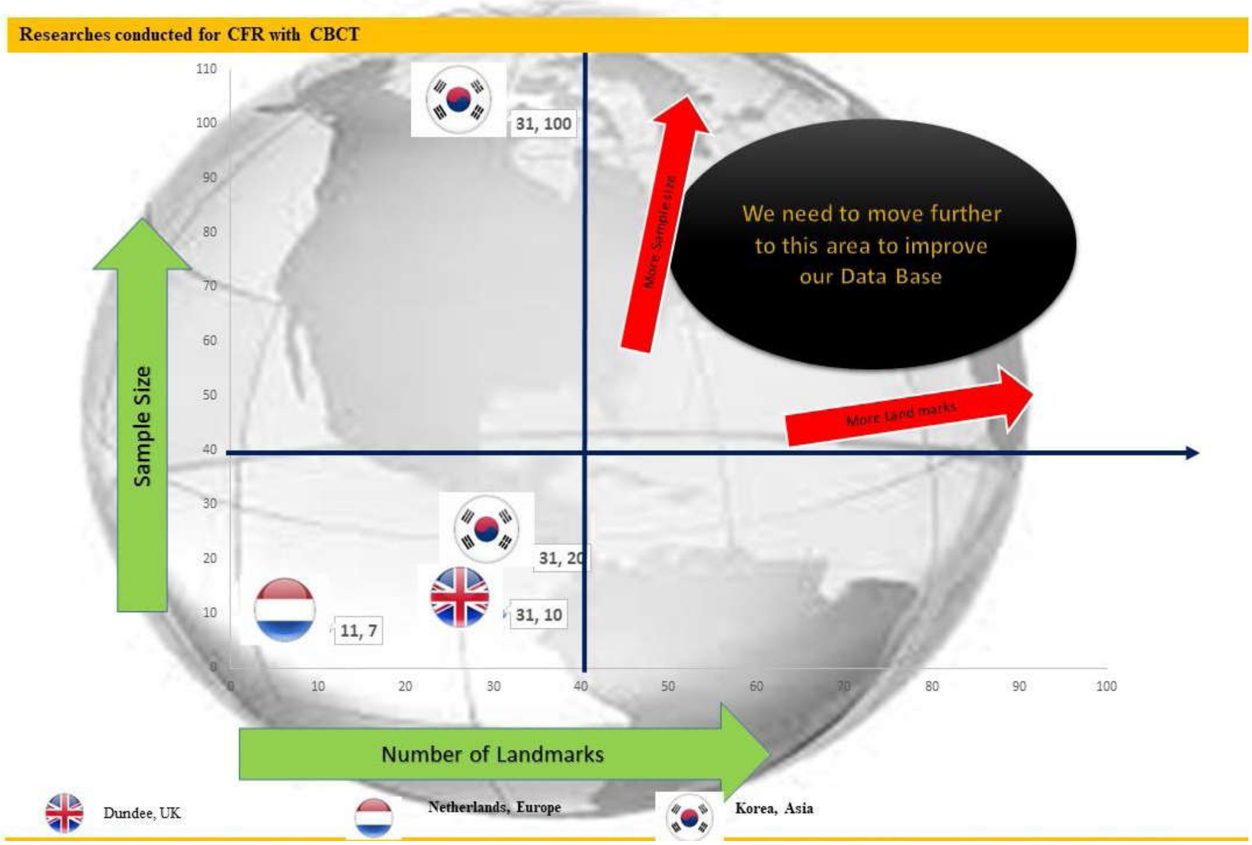

Fig. 5: Researches conducted for CFR with CBCT

low level of metal artifacts [5].

A review of literature reveals that studies have been conducted on various populationsof four races using different imaging techniques including American Blacks [23], American Caucasoid [24], Australian[25], Brazilian[26], Buryat, Korean, Kazakh, Uzbek [27], Caucasian [7], Chinese[28], Chinese–American populations [29]. Colombian adult [30], Czech [31] Egyptian [32], French [33], Hungarian [34], Indian [35] Northwest Indian [36], Indian Gujarati population [37], Japanese [38], Pakistani [39], Portuguese [40], Slovak [41], South African black [42], Turkish [43], Zulu population [44], mixed racial population [45] etc. to compile the data set (Figure 4).

In disparity, very few researches have been conducted for CFR using CBCT, in Netherlands [46] Korea [47,48] Dundee [18]. These studies comprise small sample size, varying in their method of extraction, number and position of landmarks, condition of the body and sub-categorization of the data (Figure 5).

Validation

An established method can work effectively only after it is properly validated. During criminal investigation a properly validated setup can demonstrate better results if verified before. A database of skulls with identified facial-looks is essential so that validation can be based on a leave-one-out cross-validation scenario. The identification procedure includes comparing of CFR result with a database of individuals with real facial identity a “face pool test” [6].

Conclusion

Forensic facial reconstruction using 3D CBCT retains objectivity and specialized technical training. More accurate identification of deceased can only be obtained by creating a large and diverse facial reference database. It is important to collect as much craniofacial data as possible for different populations of ancestry, age, gender,different skeletal malocclusion classesand BMI. There is also no way to confirm which method or technique provides the best resemblance to the true FSTT of humans. Also, it will perhaps never be possible to designate and predict thevast amount of face variations but still modification and enhancements of the proceduresto study associations between cranial and facial features to achieve almost adequate alikeness to the victim. For this in future stress has to be given to increase ina validated data set,with an increased number of landmarks, coding for more refined subject-specific attributes as itcan support the dependability of the soft tissue values used in reconstructions.

References

1. Valenzuela A, Marques T, Exposito N, Martín-De Las Heras S, García G: Comparative study of efficiency of dental methods for identification of burn victims in two bus accidents in Spain. American Journal of Forensic Medicine & Pathology 2002;23:390–393.
2. Stephan CN. Anthropological facial 'reconstruction' —recognizing the fallacies, 'unembracing' the errors, and realizing method limits. Sci Justice 2003;43(4): 193–200.
3. Shrimpton S, Daniels K, De Greef S, Tilotta F, Willems G, Vandermeulen D, Suetens P, Claes P. A spatially-dense regression study of facial form and tissue depth: Towards an interactive tool for craniofacial reconstruction. Forensic science international 2014; 234:103-110.
4. Wilkinson CM. Computerized forensic facial reconstruction: a review of current systems. Forensic Sci Med Pathol 2005;1(3):173–7.
5. Ajmera DH, Singh P, Song J. Soft tissue thickness determination using CBCT in diverse medical disciplines. J Pharm Biomed Sci 2015;05(12):967–972.
6. P. Claes, D. Vandermeulen, S. De Greef, G. Willems, J.G. Clement, P. Suetens, Computerized craniofacial reconstruction: conceptual framework and review, Forensic Sci. Int 2010;201:138–145.
7. De Greef S, Claes P, Vandermeulen D, Mollemans W, Suetens P, Willems G. Large-scale in-vivo Caucasian facial soft tissue thickness database for craniofacial reconstruction. Forensic SciInt 2006;159 (1):S126–46.
8. W.J. Lee, C.M. Wilkinson, H.S. Hwang, An accuracy assessment of forensic computerized facial reconstruction employing cone-beam computed tomography from live subjects. J. Forensic Sci 2012;57:318–327.
9. Q. Deng, M. Zhou, W. Shui, Z. Wu, Y. Ji, R. Bai, A novel skull registration based on global and local deformations for craniofacial reconstruction. Forensic Sci. Int 2011; 208:95–102.
10. C.N. Stephan, M. Henneberg, Building faces from dry skulls: are they recognized above chance rates. J. Forensic Sci 2001;46:432–440.
11. Fourie Z, Damstra J, Gerrits PO, Ren Y. Accuracy and reliability of facial soft tissue depth measurements using cone beam computer tomography. Forensic SciInt 2010;199 (1–3):9–14.
12. Kim KD, Ruprecht A, Wang G, Lee JB, Dawson DV, Vannier MW. Accuracy of facial soft tissue thickness measurements in per-sonal computer-based multiplanar reconstructed computed tomographic images. Forensic SciInt 2005;155(1):28–34.
13. Aulsebrook WA, Becker PJ, Ya°ar MY. Facial soft-tissue thicknesses in the adult male Zulu. Forensic SciInt 1996;79(2):83–102.
14. Krogman WM, Ya°ar MY. The Human Skeleton in Forensic Medicine. Springfield, IL:Charles C. Thomas; 1986.
15. H. Utsuno, T. Kageyama, K. Uchida, M. Yoshino, S. Oohigashi, H. Miyazawa, et al., Pilot study of facial soft tissue thickness differences among three skeletal classes in Japanese females. Forensic Sci. Int 2010; (1-3):165.e1-5.
16. S. Codinha, Facial soft tissue thicknesses for the Portuguese adult population. Forensic Sci. Int 2009; 184(1-3):80.e1-7.
17. Y. Dong, L. Huang, Z. Feng, S. Bai, G. Wu, Y. Zhao, Influence of sex and body mass index on facial soft tissue thickness measurements of the northern Chinese adult population, Forensic SciInt 2012;222(1-3):396.e1-7.
18. Short LJ, Khambay B, Ayoub A, Erolin C, Rynn C, Wilkinson C. Validation of a computer modelled forensic facial reconstruction technique using CT data from live subjects: a pilot study.Forensic SciInt 2014;237:147.e1-8.
19. S. Sipahioglu, H. Ulubay, H.B. Diren, Midline facial soft tissue thickness database of Turkish population: MRI study, Forensic Sci. Int 2012;219:282. e1–e8.
20. V. Phillips, N. Smuts. Facial reconstruction: utilization of computerized tomography to measure facial tissue thickness in a mixed racial population. Forensic Sci. Int 1996;83:51–59.
21. S. Zhou, P. Ou, M. Yu, X. Guo, C. Shao, L. He, H. Su, Cephalometric analysis of the soft tissue profile in Hunan Han adults with normal occlusion, J. Cent. S. Univ. Med. Sci 2015;40:398–405.
22. Manas Gupta, Pankaj Mishra, Rahul Srivastava, BhuvanJyoti. Cone beam computed tomography: A new vision in dentistry. Digital medicine 2015;1(1): 7-16.
23. Rhine JS, Campbell HR. Thickness of facial tissues in American blacks. J Forensic Sci 1980;4:847–58.
24. Rhine JS, Moore CE, Weston JT. Facial reproduction: tables of facial tissue thicknesses of American Caucasoids in forensic anthropology. Maxwell

Museum Technical Series1 Albuquerque, New Mexico.

25. Domaracki M, Stephan CN. Facial soft tissue thickness in Australian adult cadavers. J Forensic Sci 2006;51(1):5–10.

26. Tedeschi-Oliveira SV, HaltenhoffMelani RF, de Almeida NH, de Paiva LA. Facial soft tissue thickness of Brazilian adults. Forensic SciInt 2009;193:127.e1–7.

27. Lebedinskaya GU, Balueva TS, Veselovskaya EB. Development of methodological principles for reconstruction of the face on the basis of skull material. In: Iscan MY, Helmer RP, editors. Forensic analysis of the skull. New York: Wiley-LissInc; 1993. p.183–8.

28. Chen F, Chen Y, Yu Y, Qiang Y, Liu M, Fulton D, et al. Age and sex related measurement of craniofacial soft tissue thickness and nasal profile in the Chinese population. Forensic SciInt 2011;212:272. e1–6.

29. W.N. Chan, G.A. Listi, M.H. Manhein, In vivo facial tissue depth study of Chinese–American adults in New York City, J. Forensic Sci 2011;56:350–358.

30. Perlaza Ruiz NA. Facial soft tissue thickness of Colombian adults. Forensic SciInt 2013;229:160. e1–9.

31. A. Drgá9cová, J. Dupej, J. Velemínská, Facial soft tissue thicknesses in the present Czech population, Forensic Sci. Int 2016;260:e101–e107.

32. El-Mehallawi IH, Soliman EM. Ultrasonic assessment of facial soft tissue thicknesses in adult Egyptians. Forensic SciInt 200;117:99–107.

33. Guyomarc'h P, Santos F, Dutailly B, Coqueugniot H. Facial soft tissue depths in French adults: variability, specificity and estimation. Forensic SciInt 2013;231 (1–3):411.e1–411.e10.

34. A. Kustar, L. Forro, I. Kalina, F. Fazekas, S. Honti, S. Makra, et al., FACE-R—a 3D database of 400 living individuals' full head CT- and face scans and preliminary GMM analysis for craniofacial reconstruction, J. Forensic Sci 2013;58:1420– 1428.

35. T. Saxena, S.R. Panat, N. Sangamesh, A. Choudhary, A. Aggarwal, N. Yadav, Facial soft tissue thickness in North Indian adult population, J. Indian Acad. Oral Med. Radiol. 2012;24:121–125.

36. Sahni D, Sanjeev, Singh G, Jit I, Singh P. Facial soft tissue thickness in northwest Indian adults. J Forensic Sci 2008;176:137–46.

37. AnandLodha a, Mitalee Mehta a, M.N. Patel b, Shobhana K. Menon. Facial soft tissue thickness database of Gujarati population for forensic craniofacial reconstruction. Egyptian Journal of Forensic Sciences 2016;6:126–134

38. Suzuki K. On the thickness of the soft tissue parts of the Japanese face. J AnthropolSoc Nippon 1948; 60:7–11.

39. W. Jeelani, M. Fida, A. Shaikh, Facial soft tissue thickness among various vertical facial patterns in adult Pakistani subjects, Forensic Sci. Int 2015;257: 517.e1–e6.

40. Codinha S. Facial soft tissue thicknesses for the Portuguese adult population. Forensic SciInt 2009;184:80.e1–7.

41. P. Panenkova, R. Benus, S. Masnicova, Z. Obertova, J. Grunt, Facial soft tissue thicknesses of the mid-face for Slovak population, Forensic Sci. Int. 2012;220:293.e1–e6.

42. Cavanagh D, Steyn M. Facial reconstruction: soft tissue thickness values for South African black females. Forensic SciInt 2011;206:215.e1–7.

43. Bulut O, Sipahioglu S, Hekimoglu B. Facial soft tissue thickness database for craniofacial reconstruction in the Turkish adult population. Forensic SciInt 2014;242:44–61.

44. Aulsebrook WA, Becker PJ, Is_can MY. Facial soft-tissue thicknesses in the adult male Zulu. Forensic SciInt 1996;79:83–102.

45. Phillips VM, Smuts NA. Facial reconstruction: utilization of computerized tomography to measure facial tissue thickness in a mixed racial population. Forensic SciInt 1996;83:51–9.

46. Zacharias Fourie, Janalt Damstra, Peter O. Gerrits, Yijin Ren. Accuracy and reliability of facial soft tissue depth measurements using cone beam computer tomography. Forensic Science International 2010;199: 9–14.

47. Hyeon-Shik Hwang, Kyul Kim, Da-Nal Moon, Jae-Hyung Kim and Caroline Wilkinson. Reproducibility of Facial Soft Tissue Thicknesses for Craniofacial Reconstruction Using Cone-Beam CT Images. J Forensic Sci 2012;57(2): 443-448.

48. Hyeon-Shik Hwang, Myoung-Kyu Park, Won-Joon Lee, Jin-Hyoung Cho, Byung-Kuk Kim, and Caroline M. Wilkinson. Facial Soft Tissue Thickness Database for Craniofacial Reconstruction in Korean Adults. J Forensic Sci, 2012;57(6):1442-7.