and better accessibility and visibility during surgery.

The spoons were made of titanium, which reduces the friction between the drill and spoon, unlike the standard stainless steel spoons that produce more heat and may be abraded during function introducing metal chips inside osteotomy, which may lead to more complications [23]. The lateral arm of the spoon fits exactly in a buccal slot of the guiding sleeve in the surgical guide to secure it against movements [24].

The radiopaque composite resin (1mm diameter) was used into San reference plate to be accurately distinguished on the radiographic images. It eliminated errors that may result from scattering radiation or localizing the center of metal balls or rods used in conventional techniques [25]. The buccolingual distance between the radiographic markers did not interfere with the tongue nor with the cheek. In addition, the mesiodistal distance provided adequate landmarks.

The secured geometric transfer of the reference plate from the San mounting device to the San device enabled to view the reference points in perpendicular directions at the same height as the virtual planning. In this way the localization of the implant position was accurate in buccolingual, mesiodistal and coronoapical directions.

The calibrated transparent verification template used in this study, had no visual effect and was intimately adapted without any distortion on the monitor screen. Previous study used protractors to measure the angle manually, which lead to errors because of the distance between the protractor and the object [13].

The San device secured to surveyor model table, could be rotated freely, moved and secured in any position and angulation, due to the universal joint inside locking basket, which would enhance its precision. This is in contrast with other studies [9] that used teeth and serration in the joint, which resulted in limitation of movement and shift to the angle to the one side of tooth.

The San sleeve holder used to attach the guiding sleeve into the surgical guide without any drilling. This was accurate and simple. Many other researchers converted the radiographic template into surgical guide by drilling through the template, which resulted in vibration and movement of drilling axis leading to subsequent inaccuracy [26].

The results of this study showed that the discrepancy values obtained from the different parameters in CAD/MAM were acceptable, because of the patient's selection criteria, evaluation method and the software. This agrees with Behneke et al. (2012) who stated that, the discrepancy depends on the amount of remaining teeth and that the range of error in reduced residual dentition was 2-3 times as much as in a single tooth gap osteotomy [27].

Results of the present study were in agreement with the evidence of higher apical deviation values compared to the coronal value and also confirmed by Cassetta et al. [28]. Widmann et al. explained that it is essential to carefully distinguish between the accuracy achieved at the coronal level of the implant and the accuracy achieved at the apical level. Accuracy at the apical level is more important, as the apex is situated in the vicinity of vital anatomic structures. Naturally, the accuracy at the coronal level is always better because of the lack of angular deviation that is added by drilling further into the bone [16]. There was no statistical significant difference between the global apical deviation (GAD) of the planned and placed implants. Those results were in agreement with previous clinical studies [29], [30].

Regarding the 3D angle, a deviation of 5.14 degrees on average wasn't statistically significant. These results were in agreement with that reported by Schneider et al. (2014) who found a mean angular deviation of 5.73 degrees [30]. On the other hand, they were in disagreement with Tahmaseb et al. (2014) who recorded a maximum of 21.16 degrees [31] while in our study it was 7.1 degrees.

The global apical and global coronal deviations from this study were also comparable to those found in the study conducted by Cassetta in 2014 [32]. The results of this study supported the use of CAD/MAM, San technique as an acceptable transfer technique for fabrication of surgical guide. San device represented a handy, user-friendly and accurate tool to create manually fabricated surgical guides.

5. Conclusion

There are countless sources of error when applying guided surgery, some dependent on the operator, others not. Therefore, one needs to use ample precaution and continuous self-assessment during all steps of the planning, transfer and surgical procedure to avoid iatrogenic errors.

An individual surgical guide has proven to be useful, for the accurate placement of dental implant in the correct position. Within the limitation of this study it could be concluded that, there was no statistically significant difference neither in global parameters measured at coronal and apical level nor at 3D angle of the planned and placed implants. The use of San technique appear to be an acceptable method, for manually fabricated surgical guide, based on virtual planning of dental implant.

References

[1] D.A. Garber, U.C. Belser, "Restoration-driven implant placement with restoration-generated site development," Compend Contin Educ Dent, 16, pp. 798-802, 1995.
[2] Worthington, Philip, Rubenstein, Jeffrey, Hatcher, C. David, "The Role of Cone-Beam Computed Tomography in the Planning and Placement of Implants," JADA, 141, pp. 19S-24S, 2010.
[3] S. Cavallaro, John, Gary, Cavallaro, "Prosthodontic complications related to non-optimal dental implant placement," in Dental Implant Complications: Etiology, Prevention, and Treatment, J. Stuart, (ed.), Wiley-Blackwell, New york, p. 165, 2011.
[4] A. Sadan, A. J. Raigrodski, T. J. Salinas, "Prosthetic considerations in the fabrication of surgical stents for implant placement," IX (67), pp. 1003– 11, 1997.

[5] A. Sclar, Soft tissue and esthetic considerations in implant dentistry, Quintessence, Berlin, pp. 1-5, 2004.
[6] P.B. Tardieu, L. Vrielinck, E. Escolano, "Computer-assisted implant placement. A case report: treatment of the mandible, Int J Oral Maxillofac Implants, 18, pp. 599-604, 2003.
[7] Y. Kim, Jin, "The Implant Surgical Guide: Practical and Innovative Designs and Approaches," Dental Implantology Update, XX (10), pp. 73-80, 2009.
[8] Altug, Hasan Ayberk, Sencimen, Metin, Gulses, Aydin, "A Study of a Custom-Made Surgical Guide for Dental Implant Insertion in Free-End Saddle Sites," OHDM, III (10), pp. 152-157, 2001.
[9] Dreiseidler, Timo, "Accuracy of a Newly Developed Open-Source System for Dental Implant Planning," The International Journal of Oral & Maxillofacial Implants, 27, pp. 128–137, 2012.
[10] P. Tardieu, A. Rosenfeld, The Art of Computer-Guided Implantology, Quintessence Publishing Co., Chicago, pp. 49-57, 2009.
[11] M.Ramasamy, Giri, Raja, R. Subramonian, Karthik, R., Narendrakumar, "Implant surgical guides: From the past to the present," J. Pharm. Bioall. Sci., V (1), pp.98–102, 2013.
[12] CM. Becker, DA. Kaiser, "Surgical guide for dental implant placement," J Prosthet Dent., 2, pp. 248-51, 2000.
[13] P. Chan, F. Chik, E. Pow, T. Chow, "Stereoscopic technique for conversion of radiographic guide into implant surgical guide," Clin Implant Dent Relat Res., 15, 4, pp. 613-624, 2013.
[14] C. Marchack, P. Moy, "The use of a custom template for immediate loading with the definitive prosthesis: a clinical report," J Calif Dent Assoc, 31, 12, pp. 925-929, 2003.
[15] S.Ihde, Priciples of BOI Clinical, Scientific and Practical Guidelines to 4-D Dental Implantology, Springer,Berlin, pp.56, 2005.
[16] G. Widmann, J. Berggren, B. Fischer, A. Pichler-Dennhardt, P. Schullian, R. Bale, W. Puelacher, "Accuracy of image-fusion stereolithographic guides: mapping CT data with three-dimensional optical surface scanning," Clin Implant Dent Relat Res., 17, 2015.
[17] J. Cavallaro, G. Greenstein, "Angled implant abutments: a practical application of available knowledge," J Am Dent Assoc, 142, 2, pp. 150-158. 2011.
[18] G. De Vico, D. Spinelli, M. Bonino, R. Schiavetti, A. Pozzi, L. Ottria, "Computer-assisted virtual treatment planning combined with flapless surgery and immediate loading in the rehabilitation of partially edentulous," J Oral Implantol , 5, 1, pp. 3–10, 2012.
[19] G. Machado, "CBCT imaging a boon to orthodontics," Saudi Dent J, 27, 1, pp. 12–21, 2015.
[20] F. George, H. Chan, M. Razzoog, T. Oh, "Fabrication of a cast-based implant surgical guide using guide sleeves," J Prosthet Dent, 106, 6, pp. 409-412, 2011.
[21] J, Shotwell, E. Billy, H, Wang, T, Oh, "Implant surgical guide fabrication for partially edentulous patients," J Prosthet Dent, 93, 3, pp. 294-297, 2005.
[22] C. Park, A. Raigrodski, J. Rosen, C. Spiekerman, R. London, "Accuracy of implant placement using precision surgical guides with varying occlusogingival heights: an in vitro study," J Prosthet Dent, 101, 6, pp. 372-381, 2009.
[23] S. Meitner, R. Tallents, "Surgical templates for prosthetically guided implant placement," J Prosthet Dent., 92, pp. 569–74, 2004.
[24] M. Beretta, P. Poli, C. Maiorana, "Accuracy of computer-aided template-guided oral implant placement: a prospective clinical study," J Periodontal Implant Sci, 44, 4, pp. 184–193, 2014.
[25] Y. Huh, B. Choi, K. Huh, W. Yi, M. Heo, S. Lee, S. Choi, "In-vitro study on the accuracy of a simple-design CT-guided stent for dental implants," Imaging Sci Dent , 42, 3, pp. 139–146, 2012.
[26] S. Pattanaik, B. Pattanaik, "Fabrication of a Surgical Guide with Help of a Milling Machine by Ridge Mapping Method," J Indian Prosthodont Soc., XIII (1), pp. 61–65, 2013.
[27] A. Behneke, M. Burwinkel, K. Knierim, N. Behneke, "Accuracy assessment of cone beam computed tomography-derived laboratory-based surgical templates on partially edentulous patients," Clin Oral Implants Res, 23, 2, pp. 137-43, 2012.
[28] M. Cassetta, G. Pompa, S. Di Carlo, L. Piccoli, A. Pacifici, L. Pacifici, "The influence of smoking and surgical technique on the accuracy of mucosa-supported stereolithographic surgical guide in complete edentulous upper jaws," Eur Rev Med Pharmacol Sci, 16, pp. 1546-1553, 2012.
[29] D. Schneider, P. Marquardt, M. Zwahlen, R. Jung, "A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry," Clin Oral Implants Res, 20, 4, pp. 73–86, 2009.
[30] J, D'haese, T. Van De Velde, A. Komiyama, M. Hultin, H. de Bruyn, "Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature," Clin Implant Dent Relat Res., 14, pp. 321–335, 2012.
[31] A. Tahmaseb, D. Wismeijer, W. Coucke, W. Derksen, "Computer technology applications in surgical implant dentistry: A systematic review," Int J Oral Maxillofac Implants, 29, pp. 25-42, 2014.
[32] M. Cassetta, M. Giansanti, A. Di Mambro, L. Stefanelli, "Accuracy of positioning of implants inserted using a mucosa-supported stereolithographic surgical guide in the edentulous maxilla and mandible," Int J Oral Maxillofac Implants, 29, 5, pp.1017-1078, 2014.

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