Review Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2019;9:3s:73-83.

A Review of Various Techniques and Studies for Bone Mapping in Oral Implant Placement

Puja Hazari[1] Sunil Kumar Mishra[2*] Harsh Mahajan[3] Pankaj Mishra[4]

[1]Reader, Department of Prosthodontics, Peoples Dental Academy, Bhopal, India.
[2]Professor, Department of Prosthodontics, Peoples College of Dental Sciences & Research Centre, Bhopal, India.
[3]Professor, Department of Prosthodontics, Peoples Dental Academy, Bhopal, India.
[4]Reader, Department of Conservative and Endodontics, RKDF Dental College, Bhopal, India.

ABSTRACT

Background: The purpose of this article was to review the literature, in order to determine if ridge mapping was an accurate procedure for measurement of bone dimensions to ascertain that the dimension of an implant lies within the dimensions of available bone.

Materials and Methods: To identify suitable literature, an electronic search was performed using Medline/PubMed and Ebscohost database. Articles enumerating the various ridge mapping techniques and studies comparing ridge mapping procedure with other diagnostic aids were included in the review. Titles and abstracts were screened, and literature that fulfilled the inclusion criteria was selected for a full-text reading.

Results: The initial literature search resulted in 32 articles out of which only 18 articles fulfilled the inclusion criteria and were included in this review.

Conclusion: Various studies indicate that the ridge mapping procedures yield a good estimation of ridge dimensions, particularly in cases with adequate bone dimensions for implant treatment planning. Other diagnostic aids such as computed tomography, linear tomography and cone beam computerized tomography were indicated in cases with severe resorption.

Keywords: Caliper, Coronally, Implant Placement, Ridge mapping, Stent.

INTRODUCTION

Dental implant therapy is gaining importance day by day as the treatment of choice in cases of rehabilitation of missing dentition, complete and partial as well as for single missing tooth.[1] An important and challenging step in implant dentistry is the accurate planning and placement of the dental implant which yields a successful outcome and also prevent encroachment on vital structures.[2] Ridge mapping procedures in dental implantology proved to be a useful method due to the ease in performing, low cost, immediate results, no special armamentarium and no need of radiation exposure of patient.[3] This paper is an attempt to summarize the various techniques and comparative studies of bone mapping for oral implant placement.

MATERIALS AND METHODS

Search Strategy

A broad search of the literature in Medline/Pubmed and Ebscohost were performed for articles enumerating various ridge mapping techniques and studies comparing ridge mapping procedure with other diagnostic aids. A focus was made on peer-reviewed journals. The key words searched were ridge mapping in implantology and implant

Received: Apr. 19, 2019**: Accepted**: May. 29, 2019
***Correspondence Dr. Sunil Kumar Mishra.**
Department of Prosthodontics, Peoples College of Dental Sciences & Research Centre, Bhopal, India.
Email: drsunilmishra19@gmail.com

pISSN 2278-0076
eISSN 2321-9270

Table 1: Review of the various techniques of bone mapping.

Author/Year	Post extraction socket/Healed site	Technique	Advantages	Disadvantages
Wilson D J (1989)[4]	Healed site	Sharp points of the Wilson bone caliper penetrates the anesthetized mucosa until the surface of the bone is reached. A millimeter scale near the handle end of the caliper gives an accurate reading of ridge thickness	Simple and effective method that does not require surgical flap reflection. Radiation exposure is avoided.	Requires local anesthesia.
Sumnig W(1990) [5]	Healed site	A modified pair of bone compasses was used.	Simple and effective method	Requires modified instrument
ten Bruggenkate et al. (1994) [6]	Healed site	Ultimapper a specially designed caliper was introduced	Reliable and easy to perform.	Requires specially designed instrument
Chowdhary R(2009) [7]	Healed site	Used in flapless surgical procedure. Following implant placement an elastomeric impression is made of the abutment portion of the inserted implant, along with the adjacent teeth. The cast is sectioned adjacent to the abutment portion and the markings showing the outline of the bone on the sectioned cast are obtained by performing the ridge mapping technique. The abutment portion of the radiographic template is superimposed on the gold-color-marked abutment portion along the sectioned portion of the cast. The implant portion of the template will lie on the coronally cut section of the cast, thus showing exactly where the implant will be positioned in the bone, thus indicating the	No special armamentarium or materials required. No chances of image distortion, as well as no added cost. Helps in determining the angulations of the implant immediately after placement and also for assessing the amount of bone surrounding the implant. An interim crown may be placed on the abutment portion of the implant to evaluate the contours for the proposed restoration with the opposing cast.	Can be used only for one-piece implants.

		angulation, extension of the implant, and the surrounding bone support		
Swati et al (2010) [2]	Healed site	An acrylic resin implant placement guide based on bone mapping of the edentulous ridge was used. The die pin was inserted to separate the anterior section of the cast from the base, and a self-cure clear acrylic resin stent with seven holes were prepared 2 mm apart from each other. Bone mapping was done using the No. 20, sterile, endodontic file. The reading were calculated and transferred on to the sectioned part of the cast using the resin stent and the same endodontic file. The markings on the cast were connected to get the morphology of the bone.	It is a time-efficient procedure and can be fabricated from materials readily available. Stent can be modified as a implant placement guide.	There is a small margin of safety. Technique sensitive.
Chowdhary and Chandraker (2011) [8]	Post extraction socket	Amount of available labial and palatal bone of an extracted socket can be assessed by using the extracted tooth that is to be replaced with an endosseous implant and a ridge mapping procedure without reflecting the flap.	It is a simple technique which helps one to estimate the thickness of the labial plate, especially in the apical region and also helps to acertain if a bone graft is required. Does not require special armamentarium.	Requires local anesthesia.
Chandraker et al (2013) [9]	Post extraction socket	An impression of the arch using elastomeric impression material of putty consistency was made. Following the atraumatic tooth extraction, the extracted tooth was cleaned and reoriented in the recorded elastomeric putty	Dimensions of the implant to be placed can be determined. Can be used in root stem, fractured tooth, avulsed tooth condition where in immediate implantation is planned.	As this procedure is to be carried out immediately after the extraction, additional chairside time is needed prior to surgery.

		impression and poured in a type III dental stone. The cast was sectioned along the long axis of the extracted tooth, and the ridge mapping reading was transferred to the sectioned cast. The cast was scrapped on the labial and palatal region as per the transferred ridge mapping reading to eliminate the soft tissue covering the bone.		

Table 2: Review of the various comparative studies carried out on bone mapping.

Sr.No	Year	Author/Year	Sample size	Study	Observation	Conclusion
1	1992	Traxler et al .(1992) [10]		Data obtained from ultrasound measurement of residual ridges were compared with the data from ridge mapping with the Wilson bone caliper and the Spoerlein caliper.	The ultrasound measurement produced nearly the same data at all measurement points as ridge mapping. Ultrasound also provides exact information about the location of the mental foramen, mental nerve and the maxillary sinus.	All three methods can be successfully used in the initial stage of implant treatment planning, and that ultrasound can also correctly analyze the residual ridge diameter.
2	2000	Allen and Smith (2000) [11]	25 sites	Assess the accuracy of ridge-mapping calipers in determining bony ridge widths in the anterior maxilla prior to dental implant surgery. A modified surgical stent was designed to locate the beaks of ridge-mapping calipers at the same points on the jaw before and after mucoperiosteal	Statistically significant differences between preoperative and intraoperative measurements at both the 3 mm and 6 mm sites. Preoperative measurements tended to overestimate the amount of bone available to place the implant.	The reasons behind overestimate the bone width were calipers not completely penetrating the over- lying mucosa down to bone, which can be due to the thick mucosa following trauma. The probable explanation of under estimation of bone width may be squeezing the beaks of the

				flap reflection.		calipers too tightly, particularly in the markedly cancellous bone following extraction.
3	2005	Luis et al (2005) [12]	One site in posterior mandible in each of the 5 cadaver heads.	Compare the accuracy of linear tomography (LT) and direct ridge mapping (RM) for alveolar ridge measurements. The RM was done using vacuum-formed stents from models of the cadaver ridges at 3 sets of measurement points for each specimen. The imaging stent contained 2-mm metal balls at each point. Linear tomograms and periapical radiographs (PA) were taken of the selected sites. RM measurements were made with calipers. Mandibles were then sectioned and direct measurements (DM) were also made.	No significant differences between LT and RM for ridge width measurements. However, both techniques underestimated ridge dimensions compared to DM. Measurement of mandibular canal height was accurate when determined by periapical radiographs but not by LT.	Neither LT nor RM proved to be completely accurate in determining ridge width in the posterior mandible.
4	2008	Chen et al. (2008) [13]	25 sites	Compared ridge-mapping measurement before surgical flap reflection and measurement using images from (CBCT) to direct caliper	Comparisons of bucco-lingual ridge width using ridge-mapping versus direct caliper measurements showed that 94% and 89% of the pairs of measurement deviations were within	Ridge mapping provides measurements of the bucco-lingual ridge width consistent with those obtained by direct caliper measurement

				measurement following surgical exposure of the bone.	+/- 1 mm for both examiners. The corresponding comparison of CBCT images versus direct caliper measurements showed 70% and 55% agreement for both examiners.	following surgical exposure of the bone. CBCT was less consistent compared to direct caliper measurements.
5	2010	Fitzgerald et al.(2010) [14]	13 edentulous sites	The ridge-mapping was done using a sharp probe (DG16, Stardental). A highly restrictive model-based Nobel Guide was fabricated using preoperative bone mapping data. The stone cast was modified to represent the bone contours at the implant site. Postoperative impressions were made for comparison with the planning cast that had been used to generate the guides. A coordinated measuring device was used to obtain positional and angular information from each implant placed in the planned and postsurgical casts.	The median value for linear accuracy in three dimensions for the model-based Nobel Guide was 0.48 mm and the median angular deviation was 2.88 degrees. The greatest measured errors were still within clinically acceptable limits. The bone mapping was of sufficient diagnostic value for implant placement in sites with sufficient bone volume.(greater than 5 mm buccolingually)	A high level of linear and angular accuracy in guided implant placement seems possible with the model based Nobel Guide system.
6	2011	Luki et al.(2011) [15]	20 implant sites	Compared the relative accuracy of the ridge-mapping method against that of	Significant differences were found between CT and ridge-mapping techniques at all sites, especially	Ridge mapping is indicated only for mild or moderately resorbed cases

				standard computed tomography(CT)	in the sulcus region and the mean difference ranged from 0.3 to 0.5 mm. The direct measurements were, on average, 0.23 mm larger than cone-beam CT measurements.	with implants planned coronal to the alveolar sulcus.
7	2013	Chugh et al (2013) [16]	20	Compared and determine the clinical accuracy of three techniques, ridge mapping, direct surgical exposure, and CT scan, for measuring the alveolar ridge bone width.	Measurements were made at two points (3 mm and 6mm) from the ridge crest. The measurements of surgical exposure were taken as the control group and those obtained from the other two techniques were compared. Results suggested that there is no significant difference in the measurements obtained by direct surgical exposure technique, ridge mapping technique, and CT technique.	Use of ridge mapping technique together with panoramic and intraoral radiograph is adequate where resorption pattern appears more regular and mucosal thickness is even. It is suggested to use CT scan technique where ridge mapping is not feasible, such as resorbed alveolar ridges, presence of maxillary anterior ridge concavities, and where vestibular depth is inadequate.
8	2013	AlGhamdi AS (2013) [17]	103 implants placed in 62 patients	Investigated intra surgical and after surgical, pain and the incidence of after surgical alteration of sensation in the mandible and lower lip when placing implants in the posterior mandible using ridge mapping, panoramic	Ridge mapping was very consistent with direct measurements. Presurgical planning based on ridge mapping was similar to what was done during surgery. Panoramic radiography is a safe and predictable method for presurgical planning of dental implant placement in the	In most cases, ridge mapping, panoramic radiography, and infiltration anesthesia are sufficient for posterior mandibular implant placement without pain or complications.

				radiography, and infiltration anesthesia.	posterior mandible, provided that the magnification factor and the 2mm safety zone between the apical part of the osteotomy and the upper boarder of the Inferior alveolar nerve are kept in mind.	
9	2015	Shrikar et al (2015) [1]	Two Mandibles with 20 edentulous spaces.	Cold cure acrylic stents were fabricated on the edentulous space. Occlusally, buccally and lingually three holes were drilled and filled with gutta percha. These mandibles were then tied to the menaquine model which was fitted to a dental chair and IOPA radiographs in occlusal projection were taken. Radiographs were digitally scanned and analyzed using computer software. Direct measurements were also taken and compared.	For bone-width the mean values of clinical and radiographical method when compared by Student's unpaired t-test were 4.2525 and 4.1335 respectively. The mean values for position of center of ridge in both cases were 0.2860 and 0.2615. The sensitivity for the width of bone was 87% and that of the proposed position of center of ridge was found to be 100% . Kappa measures of agreement in both methods were statistically significant ($P < 0.001$).	IOPA radiographs in occlusal projection can be successfully used as a preprosthetic diagnostic aid. Difference between the preprosthetic position of GP point on the template and the proposed radiographic center of the ridge was 0.1164 only and width of the bone measurement using two methods was also reliable.
10	2015	Castro-Ruiz et al (2015) [3]	20 partially edentulous spaces with 62 implants sites	Vacuum-formed stent and ridge mapping caliper were used and measurement were obtained before and after surgical flap reflection. Two observers made the CBCT assessments.	No significant differences were obtained with CBCT and RM measurements ($P = 0.207$). For detecting buccal-lingual ridge, the sensitivity and specificity were 92% and 94% for CBCT and59% and 91% for ridge mapping	Ridge mapping has numerous advantages, such as no radiation to the patient, cost effective and gives immediate results for ridge bone with ideal width and height. CBCT was recommended in

					respectively.	cases of implant placement in resorbed ridges.
11	2015	Amarnath et al (2015) [18]	15 edentulous human cadaveric mandibles.	Samples were subdivided into three groups 1) Cone-beam computed tomography (CBCT) 2)Orthopantomography (OPG) 3)Direct ridge measurements (DM). The mandibles were then sectioned, and the measurements were done using a digital vernier caliper.	No significant difference was noticed among the three different measurements techniques using analysis of variance.	Study showed slight increase of 0.5 mm in CBCT measurements compared to direct ridge measurement.

diagnostic aids. Manual searches of the references of all full-text articles and relevant review articles selected from the electronic search were also performed.

Selection Criteria

To determine the studies to be included in the present review, the following inclusion criteria were applied. Articles related to ridge mapping to determine implant dimensions were only included. Only original articles were included. Both abstract and full text articles were included. Studies not meeting any of the inclusion criteria were excluded from the review. The initial literature search resulted in 32 articles out of which only 18 articles fulfils the inclusion criteria and were included in this review.

RESULTS

Literature search of Ebscohost and Medline/Pubmed databases were carried out and after assessment of the articles, 7 techniques and 11 comparative studies were selected. Review of the various techniques of bone mapping and reviews of the various comparative studies carried out on bone mapping were presented in Table 1[2,4-9] and Table 2.[1,3,10-18]

DISCUSSION

The contour of the soft tissue covering the resorbed ridges may often present a misleading picture of the extent of bone resorption.[4] The conventional ridge mapping techniques have been replaced by more advanced and latest bone imaging techniques. Cross-sectioned imaging can be achieved using computerized tomography; however, significant differences in bone height measurements have been shown to occur in comparisons of panoramic radiography and two-dimensional orthoradially formatted CT images. Problems with this technique include cumulative radiation dose to the head and neck area, the possibility of a distorted image because of metallic tooth restorations and/or patient movement, and higher cost.[19]. Even the accuracy of intraoral periapical and panoramic radiographs must be questioned because of the

possibility of image distortion and the inability to image buccolingual cross-sections.[11] Linear Tomography (LT) successfully provides cross-sectional views of proposed implant sites.[20] Linear Tomography was chosen for comparison because it is frequently used for cross-sectional imaging of edentulous jaws and is relatively inexpensive compared to CT. In addition, LT exposes the patient to less radiation than CT when used for a single site.[21] With LT, the x-ray tube moves in a straight line in one direction while the film moves in the opposite direction. Only objects lying in a plane coinciding with the pivot point of a line between the tube and the film remain in focus.[22] Studies that have assessed the accuracy of LT for implant site assessment have reported mixed results.[23,24,25].One reason for this is that blurring and magnification error can adversely affect interpretation of linear tomographic images.[25] Almog and Sanchez, in a study of 235 endosseous implants, found that LT resulted in statistically significant discrepancies between the planned prosthetic and the actual bone trajectories in the mandibular area. Mandibular molar sites had the largest discrepancies among all sites tested. No differences were found in the anterior.[25] On the other hand, Schropp et al found that conventional LT was 2.5 times more accurate in predicting implant size selection than panoramic and periapical radiographs.[26] Recently, Allen and Smith reported that 10 out of 25 maxillary anterior implants required unanticipated grafting procedures when ridge mapping had been used for preoperative ridge assessement.[11]

CONCLUSION

As advancements in precisely implemented surgical procedures for implant dentistry increase, the success rate for implant supported restorations is also increasing. Bone mapping is a simple and effective method of diagnostically measuring alveolar thickness prior to surgery. Ridge mapping is indicated for mild or moderately resorbed cases with implants planned coronal to the alveolar sulcus. Many implants are still placed without the benefit of 3D imaging because of the increased cost to the patient or lack of availability.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Desai SR, Karthikeyan I, Singh R. An in-office, cost effective technique for measuring width of bone using intra-oral periapical radiographs in occlusal projection. J Indian Soc Periodontol 2013;17(1):82-86.
2. Bhosale SS, Raman PB, Mall J. Guided implant placement in the edentulous mandible: A novel approach. J Int Clin Dent Res Organ 2010;2:30-34.
3. Castro-Ruiz CT, Noriega J, Guerrero ME. Validity of ridge mapping and cone beam computed tomography in dental implant therapy. J Indian Soc Periodontol 2015;19(3):290-293.
4. Wilson DJ. Ridge mapping for determination of alveolar ridge width. Int Oral Maxillofac Implants 1989;4:41-43.
5. Sumnig W. Determining the alveolar ridge width in planning treatment with endosseous implants. Stomatol DDR 1990;40:120-121.
6. ten Bruggenkate CM, de Rijcke TB, Kraaijenhagen HA,Oosterbeek HS. Ridge mapping. Implant Dent 1994;3:179-182.
7. Chowdhary R. A simple and practical approach to evaluate implant positioning immediately after placement. J Prosthodont 2009;18:363-365.
8. Chowdhary R, Chandraker N, Simple diagnostic method to assess the available bone for immediate implant placement in an extracted socket. J Oral Implantol 2011;37(4):473-476.
9. Chandraker N, Chowdhary R, Verma A. Technique to assess the alveolar bone width for immediate implant placement in fresh extraction sockets. Indian J Dent Res 2013;24(6):784-786.
10. Traxler M, Ulm C, Solar P, Lill W. Sonographic measurement versus mapping for determination of residual ridge width. J Prosthet Dent 1992;67(3):358-361.
11. Allen F, Smith DG. An assessment of the accuracy of ridge mapping in planning implant

therapy for the anterior maxilla. Clin Oral Implants Res 2000;11:34-38.

12. Perez LA, Brooks SL, Wang HL, Eber RM. Comparison of linear tomography and direct ridge mapping for the determination of edentulous ridge dimensions in human cadavers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99:748-754.

13. Chen LC, Lundgren T, Hallström H, Cherel F. Comparison of different methods of assessing alveolar ridge dimensions prior to dental implant placement. J Periodontol 2008;79(3):401-405.

14. Fitzgerald M, O' Sullivan M, O'Connell B. Accuracy of bone mapping and guided flapless implant placement in human cadavers using a model-based planning procedure. Int J Oral Maxillofac Implants 2010;25(6):999-1006.

15. Luk LC, Pow EH, Li TK, Chow TW. Comparison of ridge mapping and cone beam computed tomography for planning dental implant therapy. Int J Oral Maxillofac Implants 2011;26(1):70-74.

16. Chugh A, Bhisnoi P, Kalra D, Maggu S, Singh V. Comparative evaluation of three different methods for evaluating alveolar ridge dimension prior to implant placement: An *in vivo* study. J Dent Implants 2013;3(2):101-110.

17. Alghamdi AS. Pain sensation and postsurgical complications in posterior mandibular implant placement using ridge mapping, panoramic radiography, and infiltration anesthesia. ISRN Dent 2013;2013:134210.

18. AmarnathGS, Kumar U, Hilal M, Mudduganga dhar BC, Anshuraj K, Shruthi CS. Comparison of cone beam computed tomography, orthopantomography with direct ridge mapping for pre-surgical planning to place implants in cadaveric mandibles: an ex-vivo study. J Int Oral Health 2015; 7(7):1-5.

19. Schwarz MS, Rothman SC, Rhodes ML, Chafetz N. Computed tomography Part II: preoperative assessment of the maxilla for endosseus implant surgery. Int J Oral Maxillofacial Implants 1987;2:143-148

20. Ismail YH, Azarbal M, Kapa SF. Conventional linear tomography: protocol for assessing endosseous implant sites. J Prosthet Dent 1995;73:153-157.

21. Dula K, Mini R, van der Stelt PF, Buser D. The radiographic assessment of implant patients: decision-making criteria. Int J Oral Maxillofac Implants 2001;16:80-89.

22. Encyclopaedia Britannica. Tomography. In: The New Encyclopaedia Britannica, Vol 11. Chicago: Encyclopaedia Britannica; 1998:837.

23. Butterfield KJ, Dagenais M, Clokie C. Linear tomography's clinical accuracy and validity for presurgical dental implant analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:203-209.

24. Bolin A, Eliasson S, von Beetzen M, Jansson L. Radiographic evaluation of mandibular posterior implant sites: correlation between panoramic and tomographic determinations. Clin Oral Implants Res 1996;7:354-359.

25. Almog DM, Sanchez R. Correlation between planned prosthetic and residual bone trajectories in dental implants. J Prosthet Dent 1999;81:562-567.

26. Schropp L, Wenzel A, Kostopoulos L. Impact of conventional tomography on prediction of the appropriate implant size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92: 458-463.