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RESEARCH ARTICLE

COMPARISON OF VARIOUS RADIOGRAPHIC MODALITIES TO ASSESS THE BONE HEIGHT FOR IMPLANT PLACEMENT

*Krishna Chaitanya Appana, Vijaya Kumar Peddinti, Sandeep Chiramana, Durga Prasad Tadi, Ravi Kanth Anne and Sneha Deepthi Gorantla

Private Practitioner, India

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ABSTRACT

Introduction: The most advanced innovation in the last millennium was introduction of implants to dentistry. There were many advances from the onset to the current date in each and every aspect of implant dentistry. Among those advances some were a boon to the implant dentistry at the same time some were at the other side. However, implant success directly or indirectly relates when perfect pre-implant evaluation was made. Pre-implant evaluation can be done by several methods, of which radiography was widely used one because of its non-invasiveness. But the problem with radiography was the percentage of magnification.

Aim and objectives: The aim of this study is to evaluate and compare the available bone height for placement of dental implant by using Orthopantomography (OPG) and Cone Beam Computed Tomography (CBCT).

Methodology: 10 completely edentulous dry cadaver mandibles were selected for this study and radiographic markers i.e. gutta percha sticks were placed on the crest of the ridge bilaterally starting from a point just behind the mental foramen at mandibular 2nd premolar, 1st molar and 2nd molar regions and subjected to Orthopantomography (OPG) and Cone Beam Computed Tomography (CBCT). Then at all the 60 sites the mandibles were sectioned and anatomic length was measured from the crest of the ridge to the superior surface of the inferior alveolar canal by a digital caliper and the radiographic length was also measured with their respective software and finally the obtained values were statistically analyzed.

Results: A measurement error i.e. magnification of 3.11% has been noted with CBCT and 22.08% with OPG. A safety margin that is followed till date to prevent the damage to the adjacent anatomical structures has to be increased from 2mm to 2.5 to 3mm while placing implant using OPG and can be reduced to 0.5mm while using CBCT.

Conclusion: To conclude, when placing an implant taking CBCT as a guide the length of the implant can be almost the value obtained in CBCT, whereas in OPG the length of the implant should be 2.5mm less than that of the obtained value.

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INTRODUCTION

Dental implant is a renowned treatment option for replacing lost/missing natural teeth in recent time. Its boundaries have expanded at an increased pace because of its ability to restore function and aesthetics without any damage to adjacent soft and hard tissues. There are several factors that could affect the success of a dental implant. They are broadly divided into patient related factors and procedure related factors. Patient related factors include general health, habits, etc. and procedure related factors include type of the implant, surgical procedure, quality & quantity of the bone, length and width of the implant and finally the type and timing of the prosthesis i.e. superstructure. However, all these factors revolve around a prime one which is none other than bone quantity or also called as available bone (Misch, 2009). The length of the implant used for prosthetic support often corresponds to the height of available bone in the edentulous site. The length of an implant is directly related to the overall implant surface area, when all other variables are constant. A 10-mm long cylinder implant increases surface area by approximately 30% over a 7-mm long implant and has about 20% less surface area than 13-mm long implants (Misch, 1999). So, to have a good success rate one must utilize as much available bone as possible and that is the reason the available bone should be determined precisely. Available bone can be determined visually, clinically and radiographically. Visual examination is done by analysis of study casts. However, it cannot be taken for granted that the morphology of the alveolar process covered with mucosa agrees with that of the underlying bony layer. Therefore, it has been suggested to assess the size and shape of the alveolar bone by "*bone sounding*" also termed "*ridge mapping"* (Misch, 1999). But, the problem behind this bone sounding is that invasiveness of the procedure. This disadvantage has been eliminated by the advent of Radiography which is non-invasive. Radiography is an alternative, non-invasive technique which was first discovered

****Corresponding author:*** **Krishna Chaitanya,**
Private Practitioner, India

by Sir Wilhelm Conrad Roentgen in December 1895 and stated "I have discovered something interesting, but I don't know whether my observations are correct". The importance of X-rays was also recognized in dentistry only 14 days after Roentgen published his discovery. Dr.Walkhoff, a dentist first produced images of teeth (White, 2009 and Eric Whaites, 2008). From then dental professionals came to rely greatly on radiographs and scanning technology for the diagnosis and for the identification of anatomical structures for dental implant treatment planning. In order to avoid morbidity caused by the surgical procedure, it is essential to know the location of vital anatomical structures such as the inferior alveolar nerve and the extension of the maxillary sinus. Initially intraoral and panoramic radiographs are the basic imaging techniques used in dentistry and among them Panoramic radiography is considered to be the standard radiographic examination for implant treatment planning as it imparts low radiation dose and gives the best radiographic survey. But, the main drawback of these plain radiographic techniques is conspicuity, i.e., it provides only a two-dimensional view of complicated three-dimensional structures, that in turn results in magnification, distortion, superimposition and misrepresentation (Scarfe, 2008). These drawbacks have been minimized in the recent technological advancements, such as CT and CBCT. Unfortunately, among them, CT imparts high radiation dose and that dose is even higher than that of panoramic radiography and at the same time CBCT has been accredited for its least radiation dose among all the available cross-sectional radiographic modalities. Whatever may be the radiographic modality that is used to find out bone height for dental implant placement is not precise because of the amount of radiographic magnification. Everybody is aware of the radiographic magnification, but how much is that magnification is not quantified, for that reason a safety margin is left during placement of implant in the vicinity of vital structures. But, it is not possible to sacrifice the safety margin at all times, and at times we may need to use that bone also for better prognosis of the implant. So, the purpose of this study was to evaluate and compare the available bone height for placement of dental implant (between two anatomical landmarks) by using Orthopantomography (OPG) and Cone Beam Computed Tomography (CBCT).

MATERIALS AND METHODS

The present study was done in Dept. of Prosthodontics and Crown & Bridge including Implantology, SIBAR institute of dental sciences, Guntur, Andhra Pradesh to compare various radiographic methods to assess the available bone height for dental implant placement. This study was performed on 10 completely edentulous cadaver mandibles using Gutta Percha sticks (Endo-Line, Dento One Inc,Dallas) as radiographic markers. 10 completely edentulous cadaver mandibles were used to examine the accuracy of measurements of OPG and CBCT images. These selected mandibles were numbered from 1 to 10 for the purpose of identification (Lateral and frontal view of a sample numbered as 1) [Table/Fig.1,2]. Later, bilateral location of mental foramen was done on all the mandibles. Now, a small preparation of diameter and depth equal to that of a round bur was made on the crest of the ridge and the space created was filled by radiographic markers i.e. gutta percha sticks (Endo-Line, Dento One Inc, Dallas) were attached bilaterally at six locations starting from a point just behind the mental foramen [Table/Fig.3]. Each selected site allocates to a specific tooth region as per the nomenclature i.e. 37, 36, 35, 45, 46 and 47. These mandibles were now made ready for the current study. Subsequently, each mandible was subjected to CBCT (Orthophos XG 3D, Sirona Dental Systems, New York) and later to OPG (Orthophos XG5, Sirona Dental Systems, New York). Once the radiographic exposure for all the mandibles was accomplished, then the mandible was sectioned by carborundum discs (L.M.Abrasivi, Italy) at the selected sites through the markers. Now, the anatomic length from the superior surface of the inferior alveolar canal to the crest of the ridge was measured thrice for each site and an average value was noted with the help of digital vernier caliper (Baker Gauge India Private Limited, Pune). This obtained measurement was considered as gold standard [Table/Fig-4]. Later, Radiographic length was also calculated at the same sites where the anatomic length was determined using their respective software i.e. Galileos software for CBCT (Orthophos XG 3D, Sirona Dental Systems, New York) [Table/Fig-5] and SidexisXG software for OPG [Table/Fig-6]. Radiographic measurements at each site were also calculated thrice, first at mesial, middle and distal surfaces for all the markers and an average value was tabulated. The tabulated data was subjected to statistical analysis using paired t-test [Table/Fig-7]. Finally, these radiographic length measurements that were obtained from CBCT and OPG software were compared with the anatomic length for radiographic magnification using a percentage formula that was given by Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A [7] by statistical analysis using paired t-test for evaluating the amount of radiographic magnification i.e. present in each modality.

ERROR (%) = A-B÷B × 100

Here, in this formula Error denotes radiographic magnification A denotes mean value obtained by Radiographic modality either OPG or CBCT and B denotes Mean anatomic length obtained by digital vernier caliper.

RESULTS

10 completely edentulous cadaver mandibles were selected for this study in which precision and magnification of OPG and CBCT were compared with the gold standard i.e. anatomic length at all the selected 60 sites. The mean radiographic length at each selected site was noted with their respective software and has been compared with their previously obtained anatomic length. All the values obtained are tabulated and subjected to statistical analysis by paired t-test and from that mean and standard deviation are obtained at each site i.e. 35,36,37 etc. [Table/Fig-8]. Later the mean radiographic length of CBCT, OPG derived radiographic length and anatomic length at the selected 60 sites along with their Standard Deviation was calculated and tabulated. [Table/Fig-9] and finally the measurement error i.e. Radiographic magnification in percentage was calculated by the above mentioned formula which was given by Kobayshi K, Shimoda S, Nakagawa Y, Yamamoto A[Table/Fig-10].

DISCUSSION

The purpose of the pre-surgical dental implant treatment planning is to determine the size of the implant for best surgical results. To attain best results pre operative assessment should include ridge mapping and radiological examination (Sophie, 2008).

Table 1. Anatomic and radiographic length measurements at each site

Sample no	37 Mandibular left 2nd molar region			36 Mandibular left 1st molar region			35 Mandibular left 2nd premolar region			45 Mandibular right 2nd premolar region			46 Mandibular right 1st molar region			47 Mandibular right 2nd molar region		
	Anatomic Length	CBCT	OPG	Anatomic Length	CBCT	OPG	Anatomic Length	CBCT	OPG	Anatomic Length	CBCT	OPG	Anatomic Length	CBCT	OPG	Anatomic Length	CBCT	OPG
1	5.03	5.3	9.29	6.04	6.4	9.07	6.02	6.6	9.4	6.03	6	8.21	9.03	9.2	11.6	5.02	5.8	7.88
2	10.14	11.2	12.11	9.91	11.01	11.13	10.68	11.21	12.2	10.92	9.59	11.13	10.2	11.29	11.56	10	9.4	12.44
3	10.68	11.29	13.86	9.39	10.06	11.78	8.08	8.61	9.95	6.12	6.52	7.34	8.19	8.19	9.94	8.34	8.68	11.14
4	14.3	13.54	16.59	15.14	13.54	17.43	16.17	16.12	19.47	15.24	15.66	16.09	15.04	15.79	18.32	17.43	`17.15	21.56
5	8.77	9.68	11.55	9.56	9.55	11.38	8.48	9.6	10.6	12.83	13.8	16.28	11.85	11.68	14.12	10.48	10.62	12.48
6	15.49	15.5	17.16	16.54	17.18	20.6	13.73	14.58	18.38	15.34	15.46	17.82	16.61	16.6	19.44	15.44	15.71	17.46
7	12.81	12.29	16.17	12.48	13.26	16.67	13.87	15.34	17.96	8.31	8.26	8.32	9.91	9.09	10.59	8.99	9.03	11.03
8	17.29	17.69	18.58	17.12	17.44	22.74	17.56	18.75	20.82	12.41	13.99	14.07	18.62	18.63	23.07	17.11	17.72	21.02
9	11.15	11.79	14.74	12.76	12.51	13.59	10.96	12.56	13.37	13.17	14.02	16.4	9.9	11.06	12.37	9.65	9.98	11.37
10	5.01	4.3	7.88	9.04	9.3	12.1	5.03	5	6.59	5.06	5.02	8.1	5.01	5.1	7.88	5.08	5.3	6.8

Table 2. Mean and Standard deviation of CBCT, OPG and Anatomic length at 37, 36, 35, 45, 46and 47

SITE	CBCT (mm)	OPG (mm)	Anatomic (mm)
37	11.26 ± 4.11	13.79 ± 3.52	11.07 ± 4.09
36	12.02 ± 3.49	12.73 ± 4.5	11.8 ± 3.62
35	11.83 ± 4.42	13.87 ± 4.93	11.06 ± 4.22
45	10.83 ± 4.18	12.38 ± 4.17	10.54 ± 3.88
46	11.66 ± 4.19	13.89 ± 4.83	11.44 ± 4.15
47	10.93 ± 4.44	13.32 ± 5.07	10.75 ± 4.5

Table 3. Mean and Standard deviation of CBCT, OPG derived radiographic length and anatomic length

This table shows the mean radiographic length of CBCT, OPG derived radiographic length and anatomic length at the selected 60 sites along with their Standard Deviation

Groups	Mean ± sd	Minimum	Maximum
CBCT (mm)	11.6900 ± 3.97697	4.30	18.75
OPG (mm)	13.878 ± 4.3489	6.59	23.07
ANATOMIC (mm)	11.3374 ± 3.89494	5.01	18.62

Table 4. Measurement error of radiographic modalities

Measurement error in percentage was calculated by the formula which was given by Kobayshi K, Shimoda S, Nakagawa Y, Yamamoto A.

Error % = A-B÷B×100

Here, in this formula

A denotes- Mean value obtained by Radiographic modality either OPG or CBCT

B denotes- Mean anatomic length obtained by digital caliper

Error % (CBCT vs Anatomic)	= $\frac{11.6900 - 11.3374}{11.3374}$	× 100	= **3.11 %**
Error % (OPG vs Anatomic)	= $\frac{13.878 - 11.374}{11.3374}$	× 100	= **22.08 %**

Figure 1. Lateral view of sample 1

Figure 2. Frontal view of sample 1

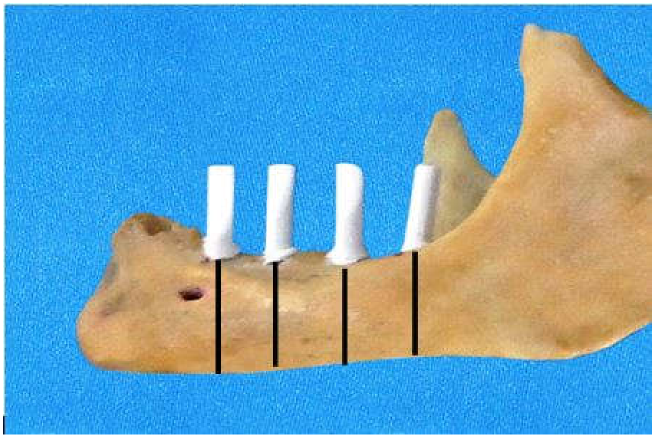

Figure 3. Placement of gutta percha at the selected locations

Figure 4. Sectioning of the mandibles at the selected sites for anatomic length calculation

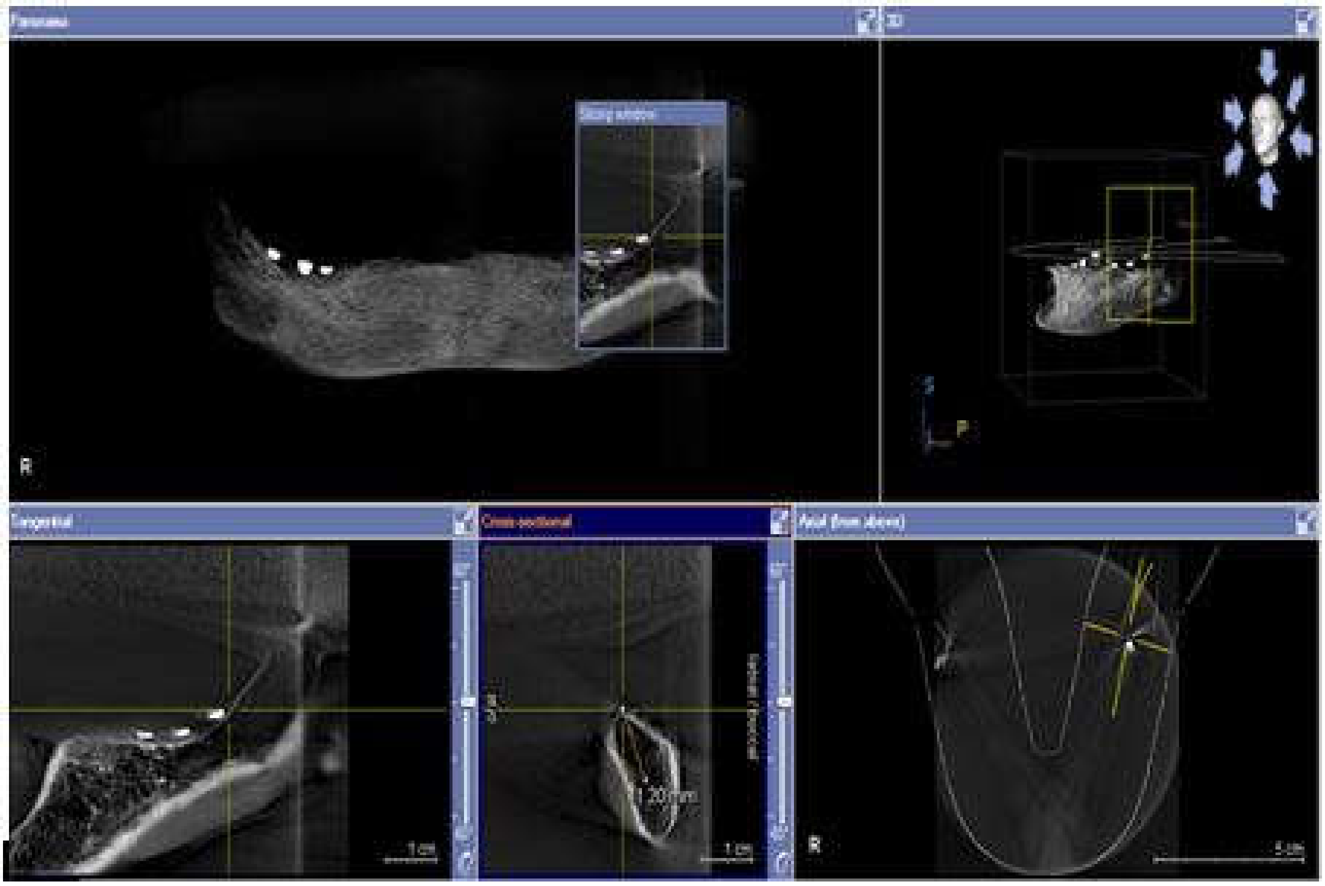

Figure 5. Radiographic length measurement using CBCT software

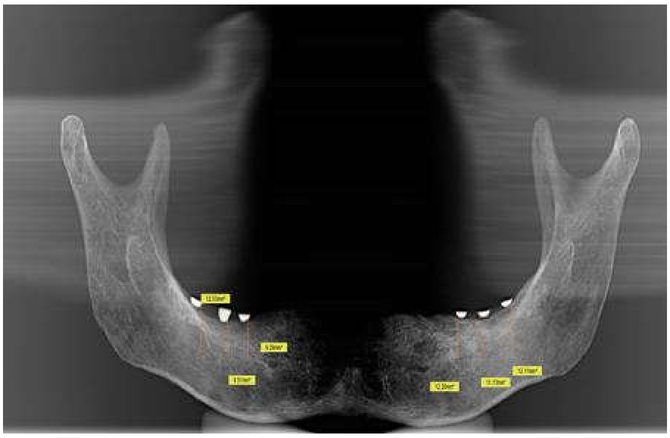

Figure 6. Radiographic length measurement using OPG software

Ridge mapping alone is insufficient to accurately predict the amount and the shape of the residual crest for implantation and for that reason radiological examination is recommended to acquire information on both quality and quantity of bone and to localize anatomical landmarks. Imaging is an important diagnostic adjunct to the clinical assessment of the dental patient. There are several radiographic methods from the past till date which help in assessing the amount of available bone in terms of height and width. They are Intra Oral Periapical radiography (IOPA), Orthopantomography (OPG), Computed tomography (CT), Cone Beam Computed Tomography (CBCT). The IOPA has been ruled out from pre implant assessment because of its limited Field of View (FOV). The advent of panoramic radiographs has been done in 1960's and its widespread adoption throughout the 1970's and 1980's heralded major progress in dental radiology, providing clinicians with a single comprehensive image of jaws and maxillofacial structures. The chief limitation of current conventional intraoral and panoramic imaging techniques is conspicuity, i.e., it provides only a two-dimensional view of complicated three-dimensional structures, that in turn results in magnification, distortion, superimposition and misrepresentation.

Numerous efforts have been made to minimize these complications in the next generation radiographic techniques by the introduction of three-dimensional (3D) radiographic imaging like CT and CBCT. Applications of CT in dentistry have been limited because of its cost, access and dose considerations. These limitations of CT lead to the advent of CBCT, which is especially dedicated for imaging the maxillofacial region. Interest in CBCT from all fields of dentistry is unprecedented because it has created a revolution in maxillofacial imaging, facilitating the transition of dental diagnosis from 2D to 3D images and expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures by way of third-party applications software (Scarfe, 2008). The main reason behind the boom for CBCT is, it has minimum radiographic dosage (29-477 μSv) among all the cross-sectional imaging modalities. CBCT provides an equivalent patient radiation dose of 5 to 80 times than that of a single film-based panoramic radiograph, 1.3% to 22.7% of a comparable conventional CT exposure (2000 μSv) and also the time taken for a CBCT ranges only from 1to 20 min depending on the machine, which is nearly half of the time taken for a CT. The cross-sectional imaging technique i.e. CBCT is recommended to accurately localize anatomical landmarks such as the mental foramen and the mandibular canal, and to obtain information on the amount of bone on the palatal side of the maxillary sinus as well as the shape and direction of the crest, particularly on areas of aesthetic concern or for the severely resorbed jaw. The drawback of CBCT is that it is incapable of discriminating soft tissue because of its low contrast resolution. However, cancellous bone in particular has been reported to be sharply visualized by CBCT, while CT didn't show cancellous bone clearly in cross sectional images of the dental arch.

Whatever may be the radiographic modality that is used to find out bone height for dental implant placement is not precise because of the amount of radiographic magnification. Quantification of that magnification is not done precisely. So, this study is to find out the accuracy and precision of these radiographic modalities i.e. OPG and CBCT. 10 completely edentulous dry cadaver mandibles were selected and radiographic markers i.e. gutta percha sticks were placed on the crest of the ridge bilaterally starting from a point just behind the mental foramen at mandibular 2^{nd} premolar, 1^{st} molar and 2^{nd} molar regions and subjected to Orthopantomography (OPG) and Cone Beam Computed Tomography (CBCT). Then at all the 60 sites the mandibles were sectioned and anatomic length was measured from the crest of the ridge to the superior surface of the inferior alveolar canal by a digital caliper and the radiographic length was also measured calculated thrice, first at mesial, middle and distal surfaces for all the markers and an average value was noted with their respective software and finally the obtained values were statistically analyzed. Munetaka N, Akitoshi K, Hiroto I, Eiichiro A conducted two experiments and one clinical study. First, the net measurement accuracy was investigated by scanning a bone mineral chart. Second, three dried mandibles were scanned both with the Direct Laser Positioning (DLP) system and Computed Tomography (CT) to assess any measurement errors, including blurs based on specific mandibular shapes. They concluded that the difference between the values obtained by the DLP system and CT was slightly larger (<1mm) in the patients than those in the dried mandibles (Munetaka, 2002).

Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A conducted a study to evaluate the accuracy of measurement of vertical distance from a reference point to the alveolar ridge. This vertical distance was measured by a caliper on the sliced mandible, and measurement error was calculated on the images produced by limited cone-beam computed tomography (LCBCT) and Spiral computerized tomography (SCT). Measurement error was determined to range from 0 to 1.11mm (0% to 6.9%) on SCT and from 0.01 to 0.6mm (0.1% to 5.2%) on LCBCT, with measurement errors of 2.2% and 1.4%, respectively (P<0.0001). To conclude LCBCT was shown to be a useful tool for preoperative evaluation in dental surgery because the relatively small field size of its images limits the patient's exposure to radiation (Kobayashi, 2004). Suomalainen A, Vehmas T, Korteniemi M, Robinson S, Peltola J studied the accuracy of linear measurements using Cone Beam CT (CBCT) and conventional Multi Spiral CT (MSCT) on the dry mandible. The distance between the marginal bone crest and the mandibular canal was measured by two observers and compared them to measurements performed with slide gauge in microradiographs of 4mm thick slices of the mandible. The measurement error (ME) showed significant differences between the methods studied (P = 0.022) the mean ME was 4.7% for CBCT and 8.8% for MSCT of the dry mandible, 2.3% and 6.6%, respectively, for the mandible immersed in sucrose solution. The measurements obtained by digital sliding caliper were slightly smaller than those obtained by CBCT and conventional spiral tomography (Suomalainen, 2008). Loubele M et al., compared the accuracy of cone-beam computerized tomography (CBCT) and multi slice CT (MSCT) for linear jaw bone measurements in an ex vivo formalin-fixed human maxilla. Before scanning, triplets of small gutta-percha markers were glued onto the soft tissues overlying the maxillary bone on the top and on both sides of the alveolar ridge to define a set of reproducible linear measurements in 11 planes and image measurements were performed by two observers. The gold standard was determined by means of physical measurements with a caliper by three observers. They concluded that both CBCT and MSCT yield sub millimeter accuracy for linear measurements on an ex vivo specimen (Loubele, 2008). From the above discussion we are aware of how radiographic modalities are necessary for successful implant planning and placement. At the same time utmost precision is also necessary while using those radiographic modalities, as we are aware of the radiographic magnification which is unavoidable. But, recent advances in radiology were strived to reduce the radiographic magnification but not completely. So, this study was done to calculate the above mentioned criteria i.e. radiographic magnification in two radiographic modalities i.e. OPG and CBCT. From the current study these inferences can be drawn, for suppose the radiographic length in OPG was found to be 14mm, but the actual length will be 10.92mm only. In the same way, if the radiographic length in CBCT was found to be 14mm, but the actual length will be 13.58mm. More the bone more the stability, finally more the success. We hope this study will make a step easier for the operator in making implant planning and placement a grand success.

Conclusion

Know safety no pain……. No safety know pain…..-Larsen & Turbo Pvt Ltd.

Within the limitations of the study the following conclusions can be drawn:

- A measurement error i.e. magnification of 3.11% has been noted with CBCT and 22.08% with OPG.
- A safety margin that was followed till date to prevent the damage to the adjacent anatomical structures has to be increased from 2mm to 2.5 to 3mm while placing dental implants in maxilla and mandible by using OPG and can be reduced to 0.5mm while using CBCT.

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