Use of CBCT in Dental Implant Treatment Planning - A Systematic Review and Meta-Analysis

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ABSTRACT

Background: With the introduction of dental implants there has been a revolution in the field of prosthetics dentistry. Dental implants can be used for rehabilitation of both partially and completely edentulous maxilla and mandible. Proper diagnosis and treatment planning are one of the important factors having important role in the successful dental implants treatment. Cone Beam Computed Tomography (CBCT) is three dimensional imaging technique being introduced recently.

Aim: This systematic review and meta-analysis was carried out with the objective of assessment of role of CBCT in the treatment planning of dental implants.

Materials and Methods: A detailed and extensive search was performed with the help of keywords CBCT, dental implants, treatment planning. There was extensive literature search in reliable and authentic databases like Pubmed, Scopus, Web of Sciences, Ovidsp for obtaining papers focussing on stroke mimics since 1980 till 2021. During the systemic review data were obtained concerning the following parameters. Type of study, nature of aim of study, number of patients and specimens included in the study in the study, imaging modality used in study, total number of implants placed, total number of implants evaluated, deviation in angulation, deviation at the entry of implants, deviation at the apex, bone height assessment, bone width assessment, bone density assessment, distance from the important anatomical structures. Then there was meta-analysis using proper statistical analysis.

Results: When there was meta analysis for different aspects of dental implants then it was found that the error in assessment of angulation of implant was minimal in CBCT with 95% CI as 0.12(-0.06,0.28) in comparison other conventional two dimensional imaging. The results of meta analysis for different aspects of dental implants showed that the error in assessment of deviation of implant at the apex and deviation of implant at the apex of implant was minimal in CBCT with 95%CI 0.10(-0.08,0.28) as in comparison other conventional two dimensional imaging. On evaluating the height, width, density of remaining alveolar bone and distance from the important anatomical structures it was found that accuracy was maximum in CBCT as compared with other conventional two dimensional imaging techniques .95% CI 0.13 (-0.07,0.28).

Conclusion: Within the limitations of this systematic review and meta analysis it can be concluded CBCT is better imaging technique in treatment planning of dental implants in comparison with other two dimensional imaging techniques but high cost and radiation exposure reduce its use for dental implant treatment planning.

Keywords: CBCT, Dental Implants, Treatment planning, systematic review and meta- analysis

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Introduction

With the introduction of dental implants there has been a revolution in the field of prosthetics dentistry. Loss of teeth due to reasons like caries, periodontitis, trauma etc is one of the major complaints with which patients report to the dental professionals. Earlier the options available for replacement of the natural teeth were fixed and removable complete and partial dentures.[1] These prostheses were found to have certain disadvantages. Removable partial and complete dentures are usually not easily accepted by the patients. There is a problem of patient compliance in using removable prosthesis. In fixed partial dentures there is good patient compliance but there is unnecessary reduction of the supporting teeth. There are also complaints of development of secondary caries, sensitivity and ultimately loss of the supporting teeth. With introduction of dental implants these problems of the contemporary removable and fixed dentures have been resolved upto a greater extent.[2]

Dental implants can be used for rehabilitation of both partially and completely edentulous maxilla and mandible. Patients who underwent rehabilitation with dental implants found to have easily accepted the treatment as well better occlusal stability, preservation of the natural teeth, improved masticatory function, improved aesthetics, better speech etc. Success of dental implants depends upon a lot of factors.[3,4]

Proper diagnosis and treatment planning are one of the important factors having important role in the successful dental implants treatment. For proper treatment planning there should be accurate analysis of the height of the remaining alveolar bone along with the accurate analysis of the width, density and quality of the available alveolar bone.[5,6] Besides there are other important factors in treatment planning of dental implants like the angulation of implants to be inserted along with distance of the dental implants from the important anatomical structures like mandibular canal, mental foramen, genial tubercle, floor of the maxillary sinus, distance from the nasal floor etc. All these factors has to be analysed precisely for proper treatment planning.[7,8]

There are several radiographic techniques being used to carry out analysis of these factors. Most of the contemporary imaging modalities like IOPAR, orthopantomography, occlusal radiograph being used for analysis of dental implants are two dimensional imaging techniques. They provide information in only two planes.[9,10] Moreover there are incidences of superimpositions and radiographic artifacts. There are also incidents of elongation and shortening of the images in these conventional two-dimensional radiographic techniques. As a results these techniques are not able to help dental professionals in proper treatment planning of dental implants.[11,12]

Cone Beam Computed Tomography (CBCT) is three-dimensional imaging technique being introduced recently. In this radiographic technique there is no shortening and elongation of image and the incidence of superimposition is also very low. Moreover the measurements carried out with the help of special software in CBCT is very precise and

accurate.[13,14] Therefore they can be used for analysis of height, width, density of the available remaining bone for placement of dental implants. CBCT can be helpful in the analysis of the angulation of the implants and distance of implants from the important anatomical structures.[15,16] This systematic review and meta-analysis was carried out with the objective of assessment of role of CBCT in the treatment planning of dental implants.

Methods and Materials

Inclusion criteria

Those published papers were selected which fulfilled following criterion:

i) Papers which reflected role of CBCT in treatment planning of dental implants.

ii) Papers which included the suitable subjects in their study having no systemic diseases affecting the prognosis of dental implants.

iii) Papers which were published in English language only.

Exclusion Criteria

Those papers were not selected which were having following features:

i) Papers which focussed mainly two-dimensional imaging techniques in implants.

ii) Those literatures published in formats which were non-commercial in nature like abstract of conference.

iii) Papers published in language other than English

Literature search

A detailed and extensive search was performed with the help of keywords CBCT, dental implants, treatment planning. There was extensive literature search in reliable and authentic databases like Pubmed, Scopus, Web of Sciences, Ovidsp for obtaining papers focussing on CBCT and implants since 1980 till 2021. A total of 127 papers were found. After those 69 papers were removed which were similar or duplicate articles. Initially there was selection of 58 distinct papers. Then after there was reviewing of abstracts and titles of papers. 37 papers were excluded after this review. Finally, 21 papers were selected which completely fulfilled the inclusion criterion and exclusion criterion. Then complete text of these 21 papers was managed. 06 more articles with full text were obtained from the references of the article. Final review was carried out and four more papers were eliminated. Hence finally 23 articles with full text were included for this systemic review and meta- analysis.

Authors of study and year of study	Study population country	Type of Study	Imaging modality used	Number of patients and study specimens	Nature of Edentulism and type of jaw involved	Number of implants placed	Number of implants underwent evaluation	Deviation in angulation of implant (°) Mean ±SD	Deviation at the entry point (mm) Mean±SD	Deviation at the apex (mm) Mean±SD
Arisan and associates. 2010b (1)	Turkey	Prospective	CBCT	53	Completely and partially edentulous . Maxillary arch and mandibular arch	294	279	5±1.66	1.7±0.52	1.99±0.64
Arisan and associates. 2010b (1)	Turkey	Prospective	CBCT	53	Completely and partially edentulous . Maxillary arch and mandibular arch	294	279	5±1.66	1.7±0.52	1.99±0.64
Arisan and associates. 2010b(II)	Turkey	Prospective	CBCT	53	Completely and partially edentulous . Maxillary arch and mandibular arch	294	279	4.73±1.28	1.56±0.25	1.86±0.4
Arisan and associates. 2010b(II)	Turkey	Prospective	CBCT	53	Completely and partially edentulous . Maxillary arch and mandibular arch	294	279	4.73±1.28	1.56±0.25	1.86±0.4
Cassetta and associates. 2012a	Italy	Retrospective	CT	10	Completely and partially edentulous . Maxillary arch and mandibular arch	116	116	.31±5.53	1.84±0.69	2.26±0.73
Cassetta and associates. 2012a	Italy	Retrospective	CT	10	Completely and partially edentulous . Maxillary arch and mandibular arch	116	116	.31±5.53	1.84±0.69	2.26±0.73
Cassetta and associates. 2013b	Italy	Retrospective	CT	10	Completely and partially edentulous . Maxillary arch and mandibular arch	111	111	3.35	1.1	1.36
Cassetta and associates. 2013b	Italy	Retrospective	CT	10	Completely and partially edentulous . Maxillary arch and mandibular arch	111	111	3.35	1.1	1.36
Cassetta and associates. 2013c	Italy	Retrospective	CT	20	Completely and partially edentulous . Maxillary arch and mandibular arch	227	227	5.09±3.7	1.47±0.68	1.8±1.03
Cassetta and associates. 2013c	Italy	Retrospective	CT	20	Completely and partially edentulous . Maxillary arch and mandibular arch	227	227	5.09±3.7	1.47±0.68	1.8±1.03
Ersoy and associates. 2008	Turkey	Prospective	CT and CBCT	21	Completely and partially edentulous . Maxillary arch and mandibular arch	94	94	5.1±2.7	1.3±1	1.6±1.5
Ersoy and associates. 2008	Turkey	Prospective	CT and CBCT	21	Completely and partially edentulous . Maxillary arch and mandibular arch	94	94	5.1±2.7	1.3±1	1.6±1.5
Ozan and associates. 2009	Turkey	Retrospective	CT	30	Completely and partially edentulous . Maxillary arch and mandibular arch	110	110	4.63±2.6	1.28±0.9	1.57±0.9

Ozan and associates. 2009 Vasakand associates. 2011	Turkey Austria	Retrospective Prospective	CT CT and CBCT	30 18	Completely and partially edentulous . Maxillary arch and mandibular arch Completely and partially edentulous . Maxillary arch and mandibular arch	110 86	110 79	4.63±2.6 3.7	1.28±0.9 0.37	1.57±0.9 0.88
Vasakand associates. 2011 Vercruyssen and associates. 2014(I)	Austria Belgium	Prospective RCT	CT and CBCT CBCT	18 59	Completely and partially edentulous . Maxillary arch and mandibular arch Completely and partially edentulous . Maxillary arch and mandibular arch	86 212	79 209	3.7 3.79±2.36	0.37 1.6±0.92	0.88 1.65±0.82
Vercruyssen and associates. 2014(I) Vercruyssen and associates. 2014(II)	Belgium Belgium	RCT RCT	CBCT CBCT	59 59	Completely and partially edentulous . Maxillary arch and mandibular arch Completely and partially edentulous . Maxillary arch and mandibular arch	212 212	209 209	3.79±2.36 3.2±2.7	1.6±0.92 1.33±0.82	1.65±0.82 1.5±0.72
Vercruyssen and associates. 2014(II) George K and associates	Belgium USA	RCT Prospective	CBCT CBCT	59 5	Completely and partially edentulous . Maxillary arch and mandibular arch Mandibular arch Partially and completely edentulous	212 5	209 5	3.2±2.7 0.026	1.33±0.82 0.035	1.5±0.72 0.026

Table 2: Meta Analysis of the assessment of angulation of dental implants using CBCT

	CBCT		2D Imaging			Mean Difference
Study or Subgroup	Mean	SD	Mean	SD	Weight	IV, Random, 95% CI
Arisan and associates 2010b (1)	5.27	0.67	3.81	0.81	7.60%	-0.54(-1.02, -0.06)
Arisan and associates. 2010b(II)	5.56	0.88	6.16	0.87	7.90%	-0.61(-1.14, -0.06)
Cassetta and associates.in 2012a	4.75	0.72	4.441	0.08	17.10%	-0.68 (-0.84,-0.54)
Cassetta and associates 2013b	7.52	0.586	4.385	0.111	7.90%	0.14(-0.38,0.65)
Cassetta and associates. 2013c	9.899	0.295	4.976	0.308	14.10%	-3.07(-3.27,-2.88)
Ersoy and associates. 2008	4.94	0.88	5.921	0.84	7.50%	0.01(-0.44,0.48)
Ozan and associates. 2009	6.41	0.1	4.851	0.73	17.20%	-0.44(-0.97, 0.07)
Vasak and associates. 2011	5.27	0.67	6.812	0.81	13.10%	-0.64(-1.02, -0.06)
Vercruyssen and associates. 2014(I)	4.239	0.939	3.812	0.647	7.60%	-0.47(-1.15, 0.00)
Total 95% CI					100%	0.12(-0.06,0.28)

Data extracted

During the systemic review data were obtained concerning the following parameters. Type of study, nature of aim of study, number of patients and specimens included in the study in the study, imaging modality used in study, total number of implants placed, total number of implants evaluated, deviation in angulation, deviation at the entry of implants, deviation at the apex, bone height assessment, bone width assessment, bone density assessment, distance from the important anatomical structures.

Statistical analysis for meta- analysis

IBM SPSS version and fourteenth version of Microsoft Excel was used for carrying out systemic review analysis. Comparison of angulation of implants, deviation at the entry and deviation at the apex among the groups was carried out with the help of independent sample t- tests while comparison of height, width, and distance from anatomical structures among groups was carried out with the help of chi square tests. Difference among the means of groups was represented with t-test confidence intervals while difference among the population was represented by chi squared confidence intervals (95% CI).

Results

Most of the studies included in the systemic review were prospective studies (44.23%) followed by the retrospective studies (23.67%). Remaining studies were belonging to other categories like randomized controlled trials, case control studies etc. The nature of most the studies were descriptive while some studies were analytical in nature. The studies were found to use CBCT as imaging modality along with CT for assessment of the treatment planning. Most of the studies (81.34%) studies were conducted after 2008. Almost populations of more than 20 countries were covered in the studies included in the systemic review. It was also observed that maximum number of studies (89%) evaluated both partially as well completely edentulous conditions. Both jaws i.e. maxilla and mandible were analysed in maximum (91%) number of studies. When there was meta-analysis for different aspects of dental implants then it was found that the error in assessment of angulation of implant was minimal in CBCT with 95%CI as 0.12(-0.06,0.28) in comparison other conventional two dimensional imaging. The results of meta analysis for different aspects of dental implants showed that the error in assessment of deviation of implant at the apex and deviation of implant at the apex of implant was minimal in CBCT with 95%CI 0.10(-0.08,0.28) as in comparison other conventional two dimensional imaging.

Table 3: Meta Analysis of the assessment of deviation at entry and deviation at apex of dental implants using CBCT

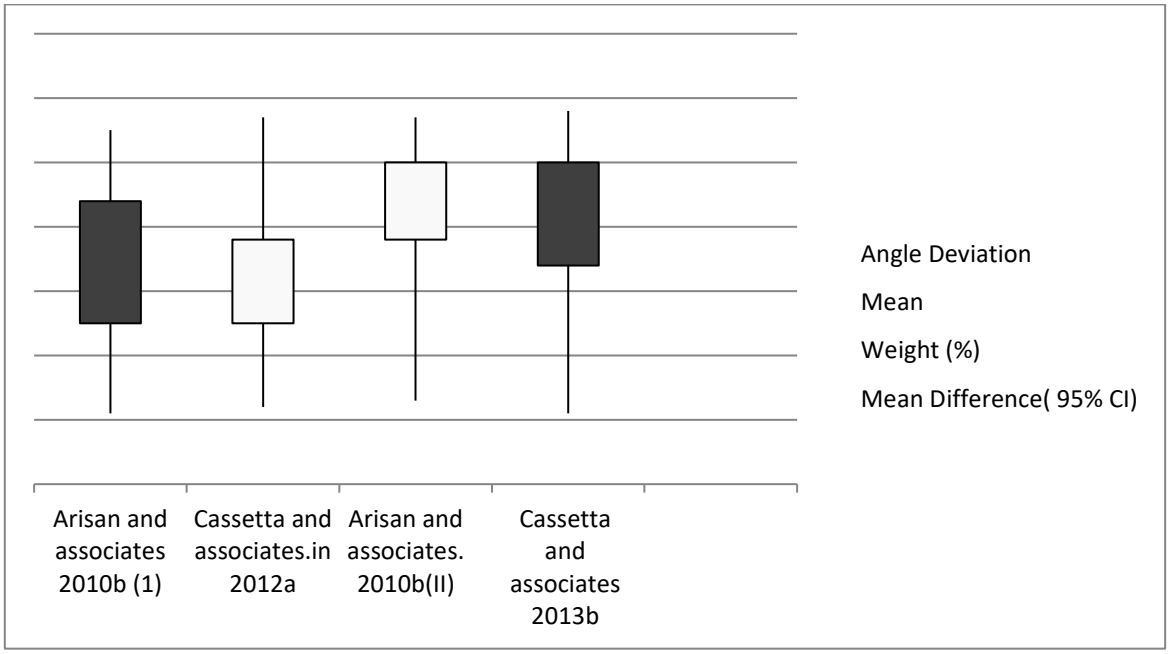
	CBCT		2D Imaging			Mean Difference
Study or Subgroup	**Mean**	**SD**	**Mean**	**SD**	**Weight**	**IV, Random, 95% CI**
Ersoy and associates. 2008	4.94	0.88	5.921	0.84	7.50%	0.01(-0.44,0.48)
Ozan and associates. 2009	6.41	0.1	4.851	0.73	17.20%	-0.44 (-0.97, 0.07)
Vasak and associates. 2011	5.27	0.67	6.812	0.81	13.10%	-0.64(-1.02, -0.06)
Vercruyssen and associates. 2014(I)	4.239	0.939	3.812	0.647	7.60%	-0.47(-1.15, 0.00)
Arisan and associates 2010b (1)	5.27	0.67	3.81	0.81	7.60%	-0.54(-1.02, -0.06)
Arisan and associates. 2010b(II)	5.56	0.88	6.16	0.87	7.90%	-0.61(-1.14, -0.06)
Cassetta and associates.in 2012a	4.75	0.72	4.441	0.08	17.10%	-0.68 (-0.84,-0.54)
Cassetta and associates 2013b	7.52	0.586	4.385	0.111	7.90%	0.14(-0.38,0.65)
Cassetta and associates. 2013c	9.899	0.295	4.976	0.308	14.10%	-3.07(-3.27,-2.88)
Total 95% CI					100%	0.10(-0.08,0.28)

On evaluating the height, width, density of remaining alveolar bone and distance from the important anatomical structures it was found that accuracy was maximum in CBCT as compared with other conventional two dimensional imaging techniques .95% CI 0.13 (-0.07,0.28).

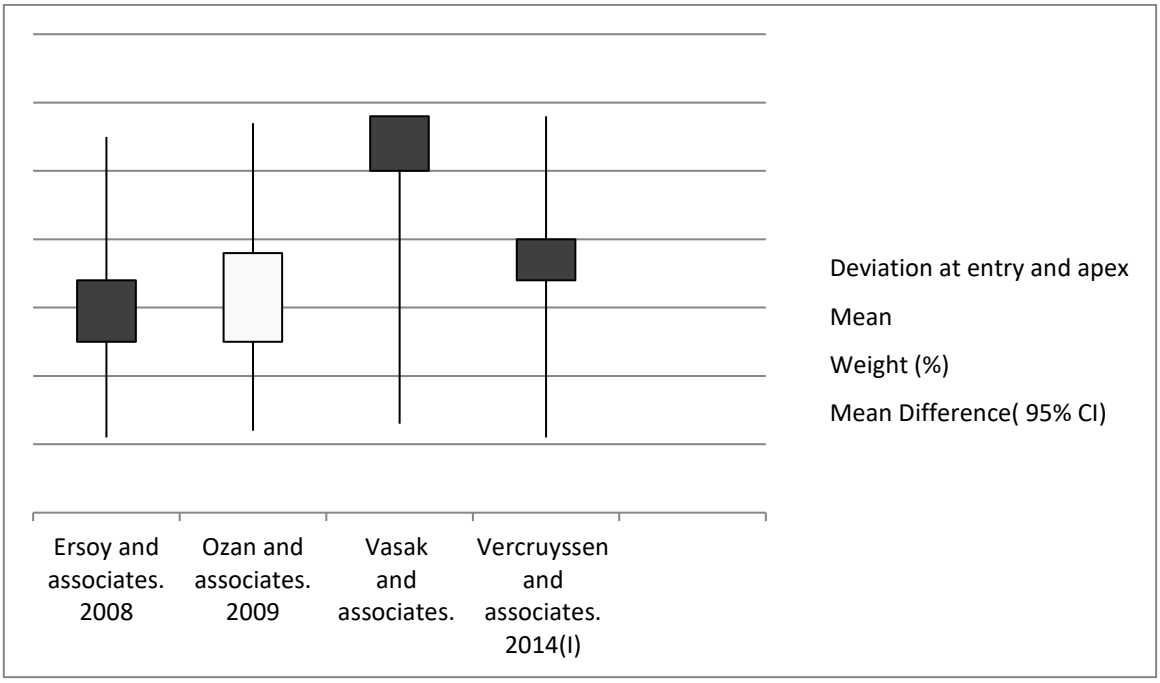
Table 4: Meta Analysis of the assessment of height, width, density of alveolar bone and distance from anatomical structures of dental implants using CBCT

	CBCT		2D Imaging			Mean Difference
Study or Subgroup	Mean	SD	Mean	SD	Weight	IV, Random, 95% CI
Cassetta and associates 2013b	7.52	0.586	4.385	0.111	7.90%	0.14(-0.38,0.65)
Cassetta and associates. 2013c	9.899	0.295	4.976	0.308	14.10%	-3.07(-3.27,-2.88)
Ersoy and associates. 2008	4.94	0.88	5.921	0.84	7.50%	0.01(-0.44,0.48)
Ozan and associates. 2009	6.41	0.1	4.851	0.73	17.20%	-0.44(-0.97, 0.07)
Arisan and associates 2010b (1)	5.27	0.67	3.81	0.81	7.60%	-0.54(-1.02, -0.06)
Arisan and associates. 2010b(II)	5.56	0.88	6.16	0.87	7.90%	-0.61(-1.14, -0.06)
Cassetta and associates.in 2012a	4.75	0.72	4.441	0.08	17.10%	-0.68 (-0.84,-0.54)
Vasak and associates. 2011	5.27	0.67	6.812	0.81	13.10%	-0.64(-1.02, -0.06)
Vercruyssen and associates. 2014(I)	4.239	0.939	3.812	0.647	7.60%	-0.47(-1.15, 0.00)
Total CI					100	0.13 (-0.07,0.28)

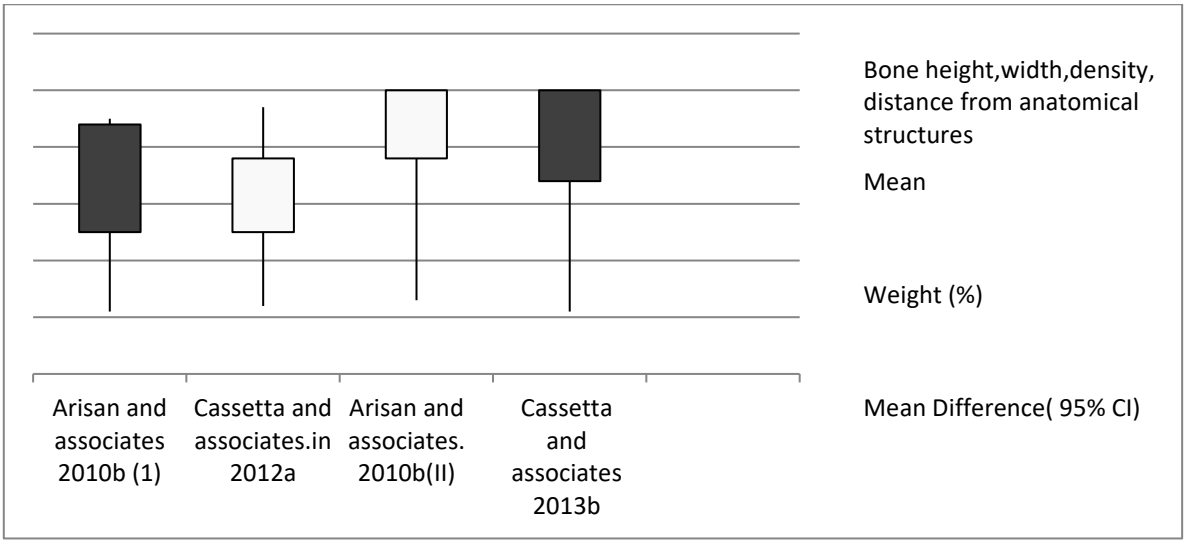
From the results of this systematic review and meta- analysis it is indicated that CBCT is better imaging modality for assessment various factors involved in the treatment planning of dental implants.



First box and whisker plot showing the results for angle deviation



Second box and whisker plot showing the results for deviation at apex and at entry of implants.



Third box and whisker plot showing the results for height , width , density of residual alveolar bone and distance from the important anatomical structures.

Discussion

One of the most significant components in the success of dental implants therapy is proper diagnosis and treatment planning. The height of the residual alveolar bone, as well as the width, density, and quality of the available alveolar bone, should be accurately measured for effective treatment planning.[17,18] Other important factors in dental implant treatment planning include the angulation of the implants to be inserted, as well as the distance of the dental implants from important anatomical structures such as the mandibular canal, mental foramen, genial tubercle, maxillary sinus floor, and distance from the nasal floor. All of these variables must be thoroughly examined.[19]

The study of these parameters is carried out using a variety of radiographic techniques. The majority of modern imaging modalities utilised for dental implant examination, such as IOPAR, orthopantomograph, and occlusal radiograph, are two-dimensional imaging approaches.[20] There are just two planes in which they provide information. Furthermore, superimpositions and radiography artefacts are common. In these traditional two-dimensional

radiography procedures, there are also instances of image elongation and shortening. As a result, these strategies are unable to assist dental practitioners in accurate dental implant treatment planning.[21]

Cone Beam Computed Tomography (CBCT) is a relatively new three-dimensional imaging technology. There is no image shortening or elongation in these radiography techniques, and the incidence of superimposition is also quite low. Furthermore, the measurements taken with the use of specialised software in CBCT are extremely precise and accurate.[22] As a result, they can be utilised to determine the height, width, and density of the residual bone for the placement of dental implants. The use of CBCT in the examination of implant angulation and distance from critical anatomical structures can be beneficial.[23] This systematic review and meta analysis was carried out with the objective of assessment of role of CBCT in the treatment planning of dental implants.

When there was meta analysis for different aspects of dental implants then it was found that the error in assessment of angulation of implant was minimal in CBCT with 95%CI as 0.12(-0.06,0.28) in comparison other conventional two dimensional imaging. The results of meta analysis for different aspects of dental implants showed that the error in assessment of deviation of implant at the apex and deviation of implant at the apex of implant was minimal in CBCT with 95% CI 0.10(-0.08,0.28) in comparison other conventional two dimensional imaging. On evaluating the height, width, density of remaining alveolar bone and distance from the important anatomical structures it was found that accuracy was maximum in CBCT as compared with other conventional two-dimensional imaging techniques .95% CI 0.13 (-0.07,0.28). From the results of this systematic review and meta-analysis it is indicated that CBCT is better imaging modality for assessment various factors involved in the treatment planning of dental implants.

There has been a revolution in the field of prosthetic dentistry with the advent of dental implants. One of the most common complaints that patients bring to their dentists is tooth loss due to caries, periodontitis, trauma, and other factors. Fixed and removable complete and partial dentures were once the only alternatives for replacing natural teeth. These prostheses were discovered to have a number of flaws. Patients frequently have a hard time accepting removable partial and total dentures.[24,25]

Patient compliance is an issue while using removable prosthesis. Patient compliance is high with fixed partial dentures; however the supporting teeth are reduced unnecessarily. There have also been reports of secondary caries developing, sensitivity, and the eventual loss of the supporting teeth. The challenges associated with today's detachable and fixed dentures have been alleviated to a greater extent thanks to the development of dental implants.[26,27] Both partially and totally edentulous maxillae and mandibles can benefit from dental implants. From the results of this systematic review it has been found that CBCT is better imaging technique for treatment planning of dental implants.

The limitations of this systematic review were that the sample size was low in most of the studies included. This is because the cost of CBCT is high. Moreover another disadvantage of CBCT is high radiation exposure.[28,29] As a result most of the study participants refuse to undergo CBCT scan. This further lead to small sample size in these studies.

Conclusion

Within the limitations of this systematic review and meta analysis it can be concluded that although CBCT is better imaging technique in treatment planning of dental implants in comparison with other two dimensional imaging techniques but high cost and radiation exposure reduce its use for dental implant treatment planning.

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