Research Journal of Biological Sciences 8 (6): 215-220, 2013
ISSN: 1815-8846

Comparison of Ridge Mapping and Spiral Computerized Tomography for Direct Measurement of Alveolar Ridge Width in Implant Dentistry

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Abstract: Implant is an available ideal treatment for replacement of missing teeth. The evaluation of bone dimension is required for treatment planning. Ridge mapping is a method that can be used for bone width determination reading which can reduce some of the complications associated with imaging techniques. The purpose of this study, was to compare the accuracy of ridge mapping and spiral computed tomography with direct bone width measurement. A total of 32 implant sites from 12 patients were used. A surgical stent was designed and used for each point of measurement in mouth and on CT images. Measurements were carried out at implant sites, 4 and 7 mm from the crest of ridge before flap reflection (RM), after bone exposure (Direct Measurement = DM) both by caliper and on the spiral CT images with digital caliper. The recorded data were analyzed using t-test. The recorded data were used to construct 36 possible pairs of data which was subsequently analyzed for statistical relation. The analysis showed that only 10 pairs out of 36 possible data pairs were significantly different. In particular, pair of RM-CT data and DM-CT data showed statistically significant difference at 7 mm levels ($p<0.05$). Of the 12 possible pair of RM-DM data, however none showed statistically significant difference at any of the 4 and 7 mm levels ($p>0.05$).

Key words: Alveolar ridge width, ridge mapping, spiral computed tomography, implants, dentistry, measurement

INTRODUCTION

The use of dental implants to support prosthodontic restorations is an important treatment choice for replacement of missing teeth (Allen and Smith, 2000; Chen *et al*., 2008; Perez *et al*., 2005). Dental implant requires accurate diagnosis, treatment planning and accurate assessment of bone dimensions to achieve the favorable results (Chen *et al*., 2008). As of these, determination of bone dimension is particularly important as implant should be ideally surrounded at least with 1 mm bone (Allen and Smith, 2000).

Several methods are available for assessing the bone quality, height and width before the surgery which include a variety of radiographic techniques ranging from peri-apical and panoramic radiographs, conventional spiral tomography or computerized tomography (Cheung, 2002). Intra oral peri-apical and panoramic radiographies, though readily available, only provide two dimensional information about implant site and may lead to inaccurate results due to inherent magnification (Allen and Smith, 2000; Danforth and Clark, 2000; Danforth *et al*., 2003; Lecomber *et al*., 2000).

Conventional and computerized tomography may be also used provide information for alveolar ridge assessment (Allen and Smith, 2000; Perez *et al*., 2005; Zieglar *et al*., 2002). Computerized techniques are the mostly used method for bone measurement due to its high accuracy (Allen and Smith, 2000). These methods, however suffer from some shortcoming, such as requiring high dose of ray, time consuming process of image preparation and finally the high financial cost of the method (Allen and Smith, 2000; Harris *et al*., 2002; Lecomber *et al*., 2001; White and Pharo, 2008). Furthermore, performance of these methods may be affected by the patient's movement and metallic tooth restoration (Allen and Smith, 2000; White and Pharo, 2008).

Ridge Mapping (RM) is another method which is used for determination of alveolar ridge width before the surgery (Chen *et al*., 2008). Ridge mapping is a quick and chair side method which can be easily and efficiently used in the clinic obviating tomographic imaging (Chen *et al*., 2008). The accuracy of this method, however has been questioned by some researches (Allen and Smith, 2000).

The aim of this study, was to compare two methods of bone width measurements namely ridge mapping before

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surgical flap (RM) and spiral CT to direct measurement following surgical exposure of the bone (DM).

MATERIALS AND METHODS

Total 12 patients (5 males and 7 females) of different ages ranging from (20-62 years) with 32 edentulous sites were involved for implant placement following clinical and radiographical examination. All the patients were checked for general health and inclusion criteria requiring a minimum distance of 7 mm from the alveolar crest to the vestibule level and giving consent to be part of the research program.

An irreversible hydrocolloid impression was first prepared and used to make the study model and then a clear acrylic stent was fabricated. The 2 pairs of buccal, lingual measurement points were defined at the site for implant placement and marked on the study model (Fig. 1). These points, positioned 4 and 7 mm from the crest of the alveolar soft tissue were transferred to the stent by drilling a guide hole of 1.0 mm diameter (Fig. 2). The stent provided consistent buccal and lingual locations for measuring the ridge width. The guide holes were filled with gutta-percha to provide radio-opaque landmarks for use during the preoperative computerized spiral tomography indicating the location for comparative radiographic ridge width measurements.

The stent with gutta-percha in the guide holes was placed in the mouth and then spiral computerized tomography was performed. The bone width was measured at all levels of 4 and 7 mm with digital caliper by a radiologist and maxillofacial surgeon with 0.01 mm precision in the direction of a line connecting the gutta-percha markers and the results was recorded in millimeter (Fig. 3 and 4). Then, gutta-percha was removed from stent for intraoral measurement before surgery. The stent was placed inside a topical solution (Betadine 10%) 24 h before intraoral measurement.

For intraoral measurement, local anesthesia was used before placing the stent inside the mouth. For each reading, the surgeon inserted the beaks into the

Fig. 1: The 2 pairs of buccal, lingual measurement points were defined at the site for implant placement and marked on the study model

Fig. 2: Surgical stent designed to locate ridge mapping callipers

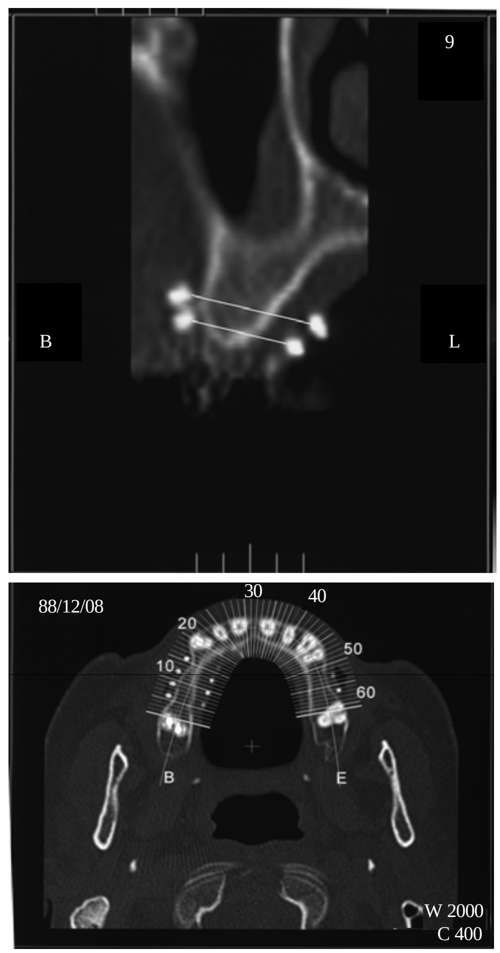

Fig. 3: Spiral CT of maxilla with gutta-percha markers

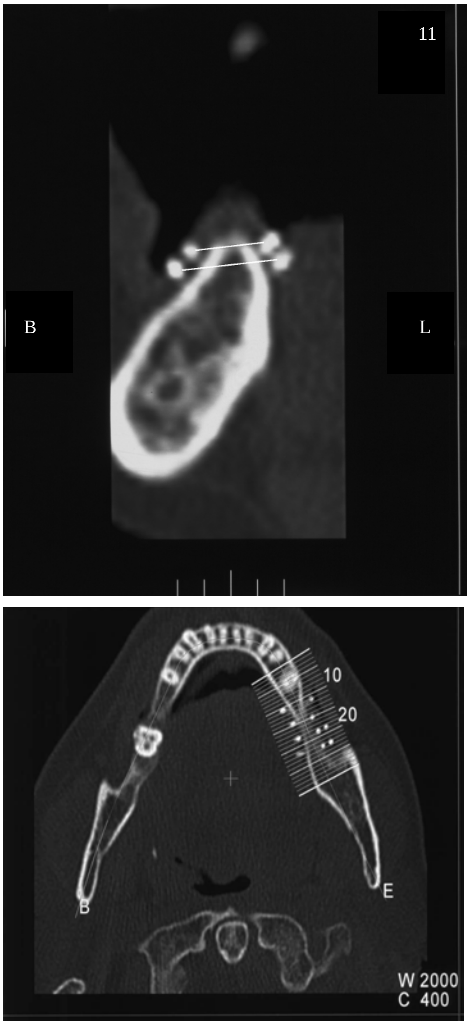

Fig. 4: Spiral CT of mandible with gutta-percha markers

appropriate alignment holes, squeezed the bone caliper handle (N: IMTEC, 2401 Oberursel, Germany) until bone was contacted. The bone width at the levels of 4 and 7 mm was then measured and recorded in terms of millimeter (Fig. 5).

Following surgical flap reflection, stent was directly placed over the exposed bone and ridge width was measured at various levels in terms of millimeter and was recorded. All the data was statistically analyzed by t-test. $p<0.05$ was considered significant.

RESULTS

This experimental study was carried out on 32 implant sites in 12 patients. The bone width was measured at the levels of 4 and 7 mm from alveolar ridge crest.

Totally, 64 intraoral measurements before flap reflection (RM data), 64 measurements after bone exposure using bone caliper (DM data) and 128 measurements on images of spiral CT (CT data) was carried out using a digital caliper by maxillofacial surgeon and radiologist.

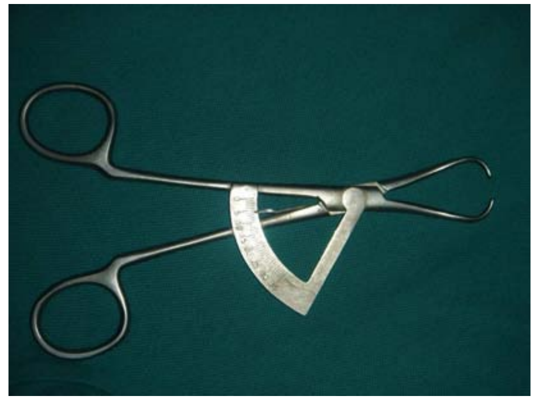

Fig. 5: Ridge mapping calipers

Table 1: Mean and standard deviation of the three set of data

Data	Level (mm)	Location	No.	Mean	SD
Ridge Mapping (RM)	4	Ant-max.	9	1.66	1.25
		Pos-max.	16	2.46	1.71
		Pos-man.	7	0.14	0.37
	7	Ant-max.	9	3.35	1.05
		Pos-max.	16	4.18	1.48
		Pos-man.	7	3.85	0.55
Direct Mapping (DM)	4	Ant-max.	9	1.52	1.31
		Pos-max.	16	2.05	1.85
		Pos-man.	7	0.07	0.18
	7	Ant-max.	9	3.30	1.04
		Pos-max.	16	3.96	1.61
		Pos-man.	7	4.21	0.48
Spiral CT data	4	Ant-max.	9	0.46	0.93
		Pos-max.	16	2.13	2.52
		Pos-man.	7	0.25	0.26
	7	Ant-max.	9	4.75	1.32
		Pos-max.	16	5.59	1.75
		Pos-man.	7	4.82	0.48

Ant-max = Anterior of maxilla; Post-max = Posterior of maxilla; Post-man = Posterior of mandible

Table 1 shows the mean value and standard deviation of the data collected by three methods of bone width measurement at 2 levels of 4 and 7 mm and 3 bone locations of anterior of maxilla, posterior of maxilla and posterior of mandible. Data of Table 1 was used to construct 36 possible pairs of data for which the mean, standard deviation and p-value representing the statistically significant difference was calculated.

Table 2 shows the mean, standard deviation and p-values for 3 possible pairs of RM, DM and CT data for all recorded data regardless of bone locations and measurement levels indicating no statistically significant differences between these three set of data.

Meanwhile, statistical comparison of the data corresponding to the anterior of maxilla, posterior of

Table 2: Analysis of the significant difference between different pairs of data

Pair of data	No.	Mean	SD	p-value
Caliper data before flap reflection (RM)	64	2.81	1.81	0.646
Caliper data after bone exposure (DM)	64	2.65	1.89	
Caliper data before flap Reflection (RM)	64	2.81	1.81	0.328
Spiral CT data	64	3.19	2.63	
Caliper data after bone exposure (DM)	64	2.65	1.89	0.183
Spiral CT data	64	38.19	2.63	

Table 3: Analysis of the significant difference between pair of data recorded at measurement level of 4 mm

Pair of data	No.	Mean	SD	p-value
RM	32	1.73	1.64	0.534
DM	32	1.47	1.65	
RM	32	1.73	1.64	0.309
Spiral CT	32	1.25	2.03	
DM	32	1.47	1.65	0.642
Spiral CT	32	1.25	2.03	

Table 4: Analysis of the significant difference between pair of data recorded at measurement level of 7 mm

Pair of data	No.	Mean	SD	p-value
RM	32	3.87	1.24	0.891
DM	32	3.83	1.30	
RM	32	3.87	1.24	0.00
Spiral CT	32	5.11	1.48	
DM	32	5.83	1.30	0.00
Spiral CT	32	5.11	1.48	

maxilla and posterior of mandible showed that none of the pairs of data had a statistically significant difference ($p>0.05$).

No statistically significant difference was, also observed for the data corresponding to the measurement level of 4 mm as seen in Table 3.

However, statistical analysis of the three set of data corresponding to the measurement level of 7 mm did not show a statistically significant difference only for the pair of RM-DM (Table 4).

Of the data acquired at the measurement level of 4 mm, those corresponding to the anterior of maxilla showed a statistically significant difference between pair of RM-CT data while those related to the posterior of mandible and maxilla did not show a statistically significant difference in any the data pairs ($p>0.05$). The statistical analysis of the data obtained at the anterior of maxilla corresponding to the measurement level of 7 mm showed that no statistically significant difference existed only between the pair of RM-DM data whereas those data corresponding to the posterior of maxilla and mandible showed no statistically significant difference only in the pair of RM-DM data ($p>0.05$).

DISCUSSION

This study showed that ridge mapping can be easily and efficiently used for determination of bone width in cases with normal conditions.

Ridge mapping was introduced by Wilson (1989) for the first time in which a bone caliper was used for the bone measurement before soft tissue reflection. No comparison, however was made between ridge mapping and other alternative methods (Wilson, 1989).

Traxler *et al*. (1992) compared ultrasound imaging with the ridge mapping and reported that ultra sound imaging enjoys enough accuracy for determination of bone width.

In another study, Behnia and Hadi (2006) compared ridge mapping with CT scan at 2 different levels of 3 and 6 mm and concluded that ridge mapping was an accurate method for measuring the bone width before implant surgery.

In a comparative study between computerized tomography, multi-slice CT and direct measurement of human cadavers, Loubele *et al*. (2007) concluded that there was no statistically significant difference between these three methods of measurement.

Abramovitch *et al*. (2003) compared spiral tomography with direct measurement of bone after flap reflection for implant placement and concluded that spiral tomography in apical and middle portion of bone did not have significant difference with direct measurement.

In another research by Cavalcanti *et al*. (1999) reformatted spiral tomography and digital caliper in Anterior of maxilla was compared and no statistically significant difference was observed.

The results of this study was in line with the finding of the previous research (Abramovitch *et al*., 2003; Behnia and Hadi, 2006; Chen *et al*., 2008; Loubele *et al*., 2007; Traxler *et al*., 1992; Wilson, 1989) emphasizing on the fact that RM is an available and useful alternative method to the CT scan for bone measurement. This was indicated by the results of the statistical analysis of the data obtained using 3 measurement methods which showed that in general there was no significant difference between these data.

To be more specific, the data shown in Table 1 was used to construct 36 possible pair of data which was subsequently analyzed for their statistical relation. The analysis showed that there was statistically significant difference between only 10 pairs out of the 36 possible pairs of data.

It is, however interesting to note that of the 10 pairs with statistically significant difference, 5 sets belonged to the pair of (RM, CT) and the remaining 5 consisted of pair of CT, DM. This means that none of the 12 possible pairs of (RM, DM) data showed statistically significant difference emphasizing on the fact that RM could be considered, as an efficient and accurate measurement method.

The fact that some of data pairs of (RM, CT) and/or (CT, RM) showed statistically significant difference has nothing to do with the efficiency and effectiveness of the RM method as the main finding of this study. It would be, however instructive to discuss why these significant differences arose.

One of the reasons for these differences can be attributed to the fact that RM sometimes over estimated the bone width, specifically at level of 4 mm in anterior of maxilla due to the existence of fibrotic changes caused by trauma and surgery, preventing the bone caliper to completely penetrate the fibrotic soft tissue.

Spongious nature of the bone at posterior of maxilla can be thought as another reason for these differences as the bone caliper generally underestimate the bone width, leading to statistically significant difference between CT data with those of RM and/or DM data.

Chen *et al*. (2008) carried out an extensive study to compare the accuracy of cone beam CT and ridge mapping using the result of a direct measurement on 25 sites and at three different levels of 4, 7 and 10 mm. Statistical analysis of the results showed no significant difference between RM and DM at both level of 4 and 7 mm while the results of cone beam CT and DM were shown to be significantly different. It should be noted that the results obtained at 10 mm level had to be eliminated due to their low accuracy caused by poor accessibility.

And last but not the least lack of appropriate access to the posterior of mandible for both effective use of bone caliper and/or ease of measurement can be considered responsible for some of differences between recorded data at this region.

This problem may have been the reason why Chen *et al*. (2008) eliminated the data collected at 10 mm level from their study (Chen *et al*., 2008). Perez *et al*. (2005) carried out a study to compare RM and linear tomography with direct measurement on human cadavers and concluded that these methods were equally inaccurate in evaluating mandibular posterior edentulous ridges. The apparent discrepancy of the results obtained by Perez *et al*. (2005) with those of other researches, including the present study can be attributed to the fact that Preze *et al*. (2005) used a digital caliper to directly measure the width of sectioned human cadavers.

The present study indicated that data from RM was consistent with data from DM as statistically there was no significant difference between RM data and DM data at various levels (4 and 7 mm). Considering the results of this study, ridge mapping can be used for bone width determination in cases with normal oral condition. But in cases with abnormal condition, such as history of trauma, surgery and poor sight and accessibility, ridge mapping alone is insufficient to accurately predict bone available for dental implant. In these conditions, spiral computed tomography can therefore be suggested for accurate and reliable bone width determination.

CONCLUSION

This study showed that ridge mapping can be used for bone width determination in cases with normal oral conditions. In cases of questionable oral conditions, such as history of trauma, surgery and poor sight and accessibility, however spiral computed tomography can be suggested.

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