Radiodensitometric Assessment Of Alveolar Cleft Grafting Using Two Different Softwares

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Abstract: Purpose: the aim of this study was to assess the bone healing after alveolar cleft grafting using IDRISI Kilimanjaro software versus direct intraoral digital radiographs (DIGORA). **Materials and Methods:** Ten alveolar clefts were grafted in nine patients (1 bilateral & 8 unilateral) of both sex (7 males & 2 females) with average age of 11.5 years at time of surgery. All alveolar clefts were grafted with autogenous bone graft harvested from mandibular symphysis. All alveolar clefts were radiographed using DIGORA immediate, 6 months, and 12 months postoperatively, densitometric analysis was performed within alveolar clefts on DIGORA image at these 3 time intervals. Another radiodensitometric analysis was performed on the same radiographic image taken by DIGORA and on the same time intervals using new computer software called"IDRISI Kilimanjaro". "Microstat 7" for windows statistical package, paired "t" test and Pearson's correlation coefficient were used for statistical analysis of the results. **Results**: Paired "t" test, revealed that there was a statistically significant increase in bone density of the grafted alveolar cleft after 12 months measured by both techniques indicating a high significant bone healing of alveolar clefts involved in this study. There was a very high positive correlation between bone density values measured by DIGORA and IDRISI techniques at all time intervals that indicate the reliability of IDRISI Kilimanjaro software for densitometric analysis of alveolar clefts **Conclusion :** IDRISI Kilimanjaro software is a valid and reliable alternative to DIGORA for radiodensitometric assessment of bone healing.

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1.Introduction

Cleft lip and palate together are the most common congenital deformity of the head and neck. A cleft is a congenital abnormal space or gap in the upper lip, alveolus, or palate, Fraser(1989).The regeneration of bone, and the osteogenic potential in osseous defects resulting from maxillary alveolar clefts are of great importance in terms of the restoration of jaw morphology and function, Kawata et al.,(2004). The primary objective of alveolar cleft grafting in cleft lip and palate patients is to provide bone tissue for the cleft site, this then allows: Maxillary arch continuity, Horswell and Henderson(2003) ,allows the eruption of teeth into the grafted area, -Peter and Larsen(2004); improves nasal symmetry, Honma et al.,(1999); Permits the orthodontic movement and the placement of osseointegrated implants when indicated, Le and Woo(2009); Improves speech, Bureau et al.,(2001); Improve oral hygiene and periodontal health, Peter and Larsen(2004); and Minimize growth disturbance, Honma et al.,(1999).

Different radiographic methods could be used for assessment of bone healing after alveolar cleft grafting, including; computed tomography(CT), Rychlik et al.,(2012), cone beam computed tomography(CBCT), El- Kassaby et al.,(2012), and digital radiography(Digora), Mikołajczak and Wilk (2007).

It was reported that, digital radiography is a reliable and versatile technology that expands the diagnostic and image referral possibilities of radiology in dentistry, Dunl and Kantor(1993); Bory and Grondahl(1996).Digital intraoral radiography must not only be capable of interpretation for apical bone lesions, investing bone defects, and assessing root canal filling, but they also be useful in diagnosis for other conditions such as in cases of radiographic follow up of bone formation after alveolar cleft rehabilitation and correction, Holtzmann et al.,(1998).

Digora uses an imaging plate (IP) that serves as x-ray image sensor for image capture called photo-stimulable phosphor plate in which plate is covered by phosphor crystals; this phosphor layer is able to store the energy of x-ray photons for sometimes.

A scanner is required to read the image information from the plate, which it does by scanning the plate with a laser beam of near- red wave lengths. The energy released from the phosphor layer, detected by an image intensifier and subsequently converted into digital image information, Reddy et al.,(1992); Bory and Grondahl (1996).

Two broad categories of data are used in the quantification of bone from digital imaging or radiograph: geometric and radiometric measurements. Geometric data include linear and angular measurements between identified landmarks. Radiometric data are used to determine relative changes in the bone density by quantifying the mean gray values of image either through density changes, through lines or by determining the region of interest (ROI), Hildebolt et al.,(1992).

In direct digital radiography, the production of image can be considered through; image acquisition, processing, storage, and image display, Lehmann et al.,(2002). The sensor or imaging plate measures the photon intensity of the x-ray beam after it has passed through the object. These measurements are done in a two-dimensional array of small regions of 20 to 30 square micrometers, called "pixels". The photon intensity is measured electronically on a scale of 256 gray values (0-255). Zero on this scale means that the maximum radiation is measured, which corresponds to black in the radiographic image, and 255 represent no radiation at all, or complete radiopacity (white). The measurements of the photons intensities for each pixel are sent to the computer and stored as an array of numbers representing the X and Y coordinates, Grondahl et al.,(1995);Hildebolt, and Vannier(1992).

The numerical information contained in this array subsequently displays the gray values on the monitor screen, Lehmann et al.,(2002). The image enhancement improves the appearance of the original image for accurate interpretation and diagnosis of dental pathologies, Huda et al.,(1996).

Mikolaiczak et al., in 2007 used Digora software (Soredex) to assess the bone grafting mineralization in patients with alveolar clefts. They found that digital radiography is very useful for establishing the scope of bone grafts, and indirectly, for assessment of its mineralization, Mikołajczak and Wilk (2007). Śmieszek-Wilczewska et al., in 2010 used Digora 2.1 software for radiographic assessment of the effects of Bio-Gen and Bio-Oss graft materials in bone regeneration of alveolar defects. Six month long follow-up period confirmed a significant increase of the optical density of regenerates augmented with Bio-Gen and Bio-Oss comparing to lesions healed without biomaterial augmentation, Śmieszek-Wilczewska et al.,(2010).

IDRISI Kilimanjarois new computer software that facilitated image restoration, enhancement, and densitometric analysis and so it was used for image analysis. Image restoration technique allows for both radiometric and geometric correction of images. The procedure is followed by image enhancement technique which allows contrast adjustment regarding all the images, and finally, followed by density measurements, Gonzalez et al.,(1992); Bernd(1993). Radwan in 2005 used Idrisi software for assessment of dental implant osseointegration and proved that, IDRISI software facilitated monitoring the changes in bone density at two zones around implant images. The first zone represented the osseointegration zone which was located just adjacent to the implant borders, along the bone-implant interface. On the other hand, the second zone was located just around the first zone and represented the bone surrounding the interface.

The purpose of this study was to assess the bone healing after alveolar cleft grafting using Idrisi Kilimanjaro software versus Digora.

2.Patients and Methods

2.1. Patients

Nine patients with alveolar clefts (1 bilateral & 8 unilateral) participated in this study. They had undergone alveolar cleft grafting to their alveolar cleft defects (ten defects) using an autogenous mandibular symphyseal bone graft. They were of both sex 7males and 2 females, their ages ranged from 12 to14 years old with an average of 11.5 years at time of surgery.

2.2.Methods:

2.2.1.Surgical Procedure

A superiorly based gingival mucoperiosteal flaps were designed on either side of the cleft. Gingival incision along the free gingival sulcus of the attached gingiva was performed and was extended to the bone. The flap on the lesser segment was extended posterior to the first molar. The gingival mucoperiosteal flap on the medial segment was elevated in a similar fashion to the midline and occasionally beyond that as needed.

A dissecting scissor was used to perform submucosal dissection superior to the oro-nasal fistula and to separate the muscles and connective tissue from the nasal mucosa as extend to the base of the upper lip. The nasal mucosa was dissected from the labial mucosa at both medial and lateral margins of the cleft. The nasal mucosa was also separated from the palatal mucosa till the depth of the defect. (Figure1, 2)

Fig. 1: Preoperative alveolar cleft

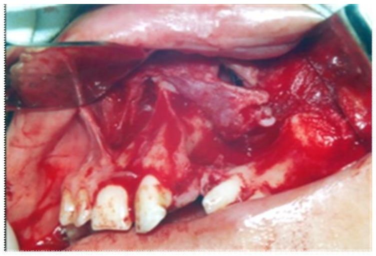

Fig. 2: Separation of nasal mucosa from labial & palatal mucosa

In the current study, some patients had palatal fistulae in addition to the labial fistulae. For those patients a gingival incision was made for at least a distance of two teeth on each side of the palatal cleft. A periosteal elevator was used to elevate a palatal mucoperiosteal flap along the margins of the palatal defect. In the created palatal subperiosteal tunnels blades of the dissecting scissor was inserted to separate the nasal mucosa from the palatal mucosa. The nasal mucosa was then closed with interrupted suture using 4/0 vicryl suture& 3/4 needle.
(Figure 3)Palatal flap was then closed also using 4/0 vicryl suture & 3/4 needle to close palatal cleft.

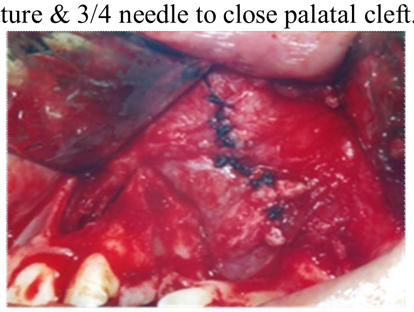

Fig. 3: Closure of nasal mucosa

After exposure of the symphysis, trephine bur No. 6 was used for collecting the symphyseal bone graft which consists of cortical and cancellous bone, leaving lingual cortex intact. After freeing the bone graft segment from the symphysis, the field was irrigated with saline and soft tissue was replaced and sutured with interrupted suture using 3/0 vicryl suture. Particulate bone graft was firmly packed into the pear-shaped cleft defect.

The lateral mucoperiosteal flap was then advanced medially to cover the bone graft and closed to the medial gingival flap and palatal mucosa with a 4/0 vicryl suture. In cases suffering from labial and palatal fistulae, the labial flaps were secured to the palatal flaps with 4/0 vicryl suture closing four corners of the four flaps on the crest of the ridge to provide a watertight seal and tension-free closure.(Figure 4-6)

Fig. 4: Bone harvesting from mandibular symphysis

Fig. 5: Application of bone graft in alveolar defect

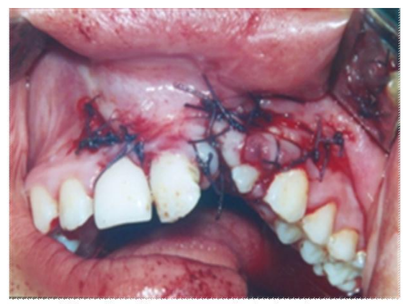

Fig. 6: Closure of cleft site

2.2.2.Post-operative Care:

1. Extra-orally, elastic tapes covering the submental region and the upper lip were applied as a pressure bandage to decrease postoperative edema.
2. Post-operatively, intramuscular injection of Unasyn 750 mg every 12 hours was prescribed for 3 days then the rout of administration of Unasyn was changed from intramuscular to oral rout (375mg tablet every 8 hours) for another 4 days post-operatively. One single dose of Depomedrol 80 mg was injected intramuscularly immediately postoperative. Voltarine 75 mg was injected intramuscularly every 12 hours for three days, then changed into Brufen (200mg) syrup was given once needed for control of pain.
3. Local decongestant Afrine nasal drops every 8 hours for ten days with systemic antihistaminic Telfast tablet 120mg once daily for ten days.
4. Post-operative instructions included using cold applications in the form of ice bags ten minutes every half an hour for the six hours post-operative. The patient was instructed to avoid anything which

causes negative or positive pressure inside the nasal cavity such as oral and nasal blowing.

5. Hexitol mouth rinse 3 times daily was used pre-operative and for at least 2 weeks after the operation. Liquid diet was given for 2-3 days postoperative; then a soft diet was given for two weeks, after which a normal diet was resumed.
6. Digital radiographs were obtained as soon as the patient condition permitted within the first 10 days after the operation.

2.2.3.Digora procedure for densitometric analysis:

Intraoral direct digital radiographs were taken for all patients involved in this study, immediately after surgical operation, suture removal and clearance of surgical edema then after 6 and 12 months postoperatively.

Radiographic standardization and reproducibility were carried out through:

1. XCP (Rinn's type): anterior XCP film holder type.
2. Custom made radiographic template was made from soft acrylic resin for each individual.
3. Exposure parameters: the imaging plate (IP) was exposed to x-ray using Trophyx-ray machine at 65 kilo-voltage (KV) and 10 miliampere (mA), for 0.04 seconds with the central rays perpendicular to both examined teeth and the IP. The exposure parameters were considered fixed for all patients during the follow up periods.
4. Long cone: 16 inch in length was mounted to x-ray tube and the plastic aiming ring of the XCP film holder was fixed flush ended with the rounded end of the long cone.
5. Digora system (intraoral direct digital radiography) Direct standardized digital images were taken using Digora system; an imaging plate (IP) with dimensions equal to 1.6 x 35 x 45mm was used. The IP was mounted to the film backing plate then the template was attached to it by fitting the acrylic projections of template to the holes corresponding to them in the bite block and then inserted in the patient mouth. After exposure, IP was removed from its envelop and gently placed into the scanner opening and retained in position by a magnet, the scanner door was closed.

Image read out was displayed automatically on the computer screen. When the read out was completed, the new image was stored in the active patient's card. The stored images of each patient were interpreted at the end of the follow up periods by one observer at two different times to decrease observer errors, and the mean value was calculated.

2.2.4.Image processing and analysis:

Image processing enhances the image visualization through using special software within the machine and to adjust image contrast, density and sharpness. Image analysis include both geometric and radiometric measurements, Gonzalezet al.,(1992).

<u>Measurement of bone density of the alveolar cleft area:</u>

Using Digora software, a line A was extended tangent to the apices of the teeth bounded the cleft area, also a line B was extended from the cemento-enamel junction of the same teeth.

Then, three lines were traced:

The first line (i):

Was made parallel to the distal tooth root bounded the cleft area,

The second line (ii) :

Was made parallel to the mesial tooth root bounded the cleft area, then

The third line (iii) :

Was extended from the middle of the previous two lines (i ,ii).

All the three lines (i, ii, iii) were extended to connect line A and line B respectively. The length and position of these lines were considered fixed in each patient during the whole follow-up period. The density measurements through the three lines were calculated, the density value was obtained. (Figure 7)

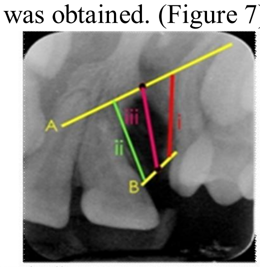

Fig. 7: Densitometric analysis procedure within alveolar cleft using Digora

2.2.5.IDRISI procedure for densitometric analysis:

IDRISI Kilimanjaro software was used for another radiodensitometric analysis on the same radiographic image taken by intraoral direct digital radiographs and at the same time intervals. IDRISI is a raster-based image processing program inspired by Clark Labs, Clark University, USA. The software analyze the images through the following steps; image restoration, image enhancement and density measurements. The measured cleft areas are bounded by the proximal surface of adjacent teeth, alveolar crest, and a line extended tangent to the apices of the teeth bounded the cleft area.. On each image, an analysis of the changes in the mean gray value was performed using the polygon measurement facility of the used software. The unit of measurement for bone density is pixels (mean gray value). The density measurements were calibrated by quantifying the image on 256 grey-scales. Zero scale are given to the totally black regions, 256 for totally white regions and the values in between represent shades of grey, Gonzalez et al.,(1992); Bernd

(1993); Dawoud(2009). Each of these values corresponded to the mean density of the cleft area .These measurements were performed by the same investigator twice in an attempt to eliminate intra-observer error.(Figure 8)

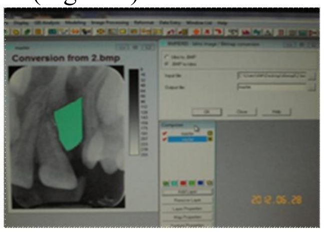

Fig. 8: Densitometric analysis procedure within alveolar cleft using IDRISI

2.2.6.Statistical analysis

Microstat7 for windows statistical package was used for statistical analysis of all data and Paired "t" test for comparison between both readings in each technique. Pearson's correlation coefficient was calculated to evaluate Idrisi in contrast to Digora.

3.Results:

The raw data of densitometric analysis for the cleft patients measured by both Digora and IDRISI Kilimanjaro softwares were tabulated for statistical analysis. All the statistical results considered to be significant at P value < 0.05.

Using paired "t" test, there was a statistically significant increase in bone density of the grafted alveolar cleft after 12 months measured by both techniques (Table 2 & Figure 9).

There was a very high positive correlation between bone density values measured by Digora and IDRISI techniques at all-time intervals ("r" value = 0.92, 0.98, 0.94 at immediate, after 6 and 12 months respectively), indicating that IDRISI Kilimanjaro software is a reliable alternative technique to DIGORA for densitometric analysis of alveolar defects. (Table 3) & Figure (10-12)

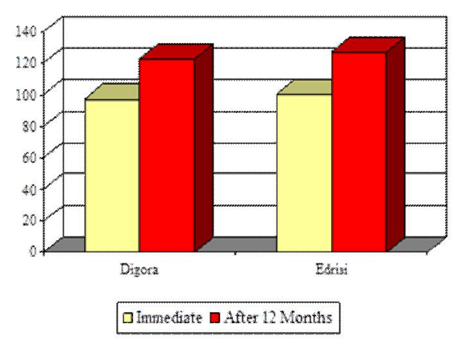

Fig. 9: Comparing the mean values of bone density readings measured by each technique in the two time intervals

Table 1: Bone density readings for all alveolar clefts by both techniques

Patient number	*Follow up intervals*	*DIGORA*	*IDRISI*	*Standard deviation (Idrisi)*
1	Immed.	74.3	59.5	±20.5
	6m	103	106	±14.9
	12m	117.6	118.7	±10.1
2	Immed.	97.3	97.2	±6.8
	6m	104	108.8	±11.05
	12m	113	119.9	±10.4
3	Immed.	137.3	134.6	±3.1
	6m	139.3	135.1	±8.4
	12m	115	105.3	±11.8
4	Immed.	112.6	120.9	±15.7
	6m	142.6	141.6	±9.9
	12m	156	158.9	±14
5	Immed.	106.6	110.2	±6.4
	6m	158.6	159	±13.9
	12m	132.6	131	±8.9
6	Immed.	77.6	81.9	±17.9
	6m	96	99.3	±10.7
	12m	97	109.5	±10.13
7	Immed.	108	115.5	±13.4
	6m	72.6	87.4	±24.2
	12m	103.3	107.2	±8.3
8	Immed.	84.3	87.3	±13.4
	6m	132.3	139.6	±22.2
	12m	135.6	139.6	±8.9
9	Immed.	99.3	105.9	±18.1
	6m	132.6	136.3	±7.2
	12m	153	164.8	±10.4
10	Immed.	74.3	92.8	±29.3
	6m	97.6	112.5	±24.7
	12m	102.3	116.5	±22.2

Table 2: Effect of time on bone density of alveolar cleft in both techniques

Technique	**Bone Density**		**"t" value**	**Probability**
	Immediate	***After 12 months***		
Digora	97.16 ± 20.15	122.54 ± 20.88	3.266	0.01 *
Idrisi	100.58 ± 21.60	127.14 ± 21.13	2.95	0.01 *

Table 3: Correlation between bone density values by Digora and Idrisi

Bone density	**"r" value**	**Prob**
Immediate	0.92	0.00001
After 6 Months	0.98	0.000001
After 12 Months	0.94	0.00001

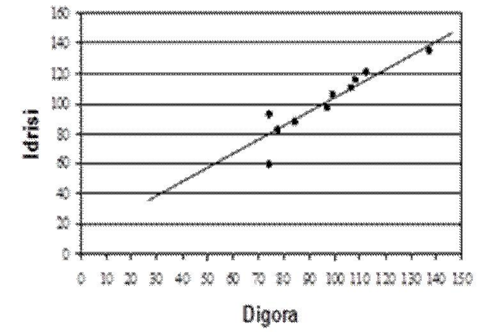

Fig. 10: The correlation between bone density values of the grafted alveolar cleft measured by both techniques at immediate follow up period.

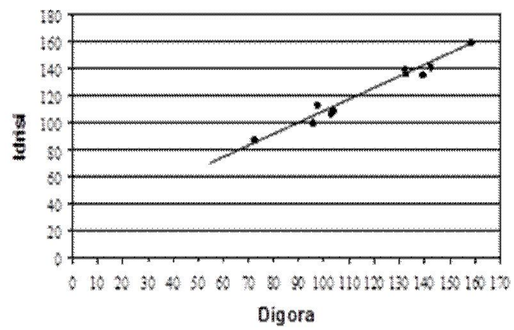

Fig. 11: The correlation between bone density values of the grafted alveolar cleft measured by both techniques after 6 months

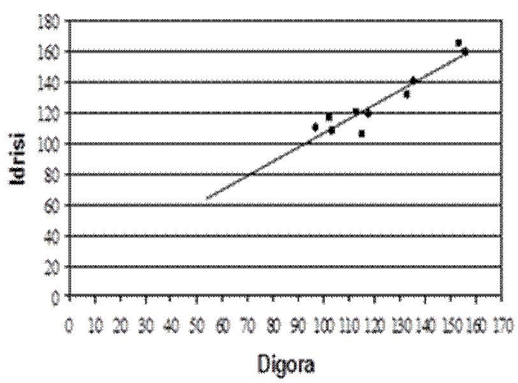

Fig. 12: The correlation between bone density values of the grafted alveolar cleft measured by both techniques after 12 months

4. Discussion

Direct digital radiography is mainly utilizing an intraoral detector to capture a radiographic image of the diagnostic area of interest, Jeffcoat(1992) . Direct digital imaging has the advantages of allowing: Consistent image quality, immediate image viewing, elimination of the darkroom, improved detection and interpretation of lesions / diseases, electronic image processing, remote consultation capability, reduced exposure to x-ray, and elimination of hazardous chemicals, Miles and Van Dis(1999).

Direct digital radiography offers other advantages for intra-operative use: the solid state detector replaces film, so there is no delay while the film is chemically processed, the contrast and brightness of the image can be easily adjusted on the monitor so that different structures can be visualized, since the image is digital, it can be stored on a disk to facilitate measurements of bone loss or bone gain along the root surface, and overcoming the shortage of indirectly digitizing a film through a camera or scanner, Reddy et al.,(1992); Wenzel(1999).

In comparison with CT and CBCT which are also available for assessment of alveolar cleft grafting, DIGORA is the cheaper method of assessment and delivers the lowest radiation dose to the patient during exposure, Wenzel(1999); Chau and Fung(2009).

Digital radiography provides a proper tool for diagnosis of caries, periodontitis and periapical disease; for three-dimensional viewing of the teeth and supporting structures; and analysis of trabecular bone pattern for early detection of systemic disease as well as measuring of bone density. Hardware of direct digital radiographs provides increased dynamic range and sensitivity to radiation, and improved resolution. Sensors are made the size of film, and components are interchangeable across manufacturers, Stuart et al.,(1999). Incorporation of density standards into receptors allow accurate measurement of object mass leading to measurement of mineral gain or loss, such as in caries or periodontal or periapical disease. Changes in bone mass may also be useful for detecting disease progression or resolution. In this fashion, digital radiography provides a precise quantitative diagnostic tool, Parks and Williamson(2002). For all these previous reasons, DIGORA software was the technique of choice to be used in our study for densitometric analysis and assessment of bone healing of alveolar clefts.

IDRISI Kilimanjaro software was selected at this study to be calibrated for densitometric analysis of the alveolar cleft area as it is available cheap and accurate tool for that purpose. IDRISI software gives the mean bone density at the area of alveolar cleft with the standard deviation and the degree of freedom in an accurate way. IDRISI software could be used as an alternative to DIGORA in densitometric analysis to overcome its disadvantages which includes; higher cost, unknown life expectancy of sensor, special training of dental auxiliaries, and charged-coupled device (CCD) sensor must be wired to the computer, Reddy et al.,(1992);Wenzel(1999).

This is in agreement with Radwan in 2005 who conducted a study to evaluate osseointegration around delayed-immediate implants using IDRISI Kilimanjaro software. The study proved that IDRISI Kilimanjaro software is an accurate tool for densitometric analysis, Radwan(2005). Dawoud in 2009 used IDRISI software for evaluation of osseointegration of immediate dental implants in two groups of patients and stated that IDRISI software is a valid and reliable technique for radiodensitometric analysis around dental implants which is consistent with the results of our study, Dawoud (2009).

The significant increase in bone density seen after 12 months postoperatively means a significant bone formation by time at the areas of alveolar cleft involved in our study and supposed that IDRISI Kilimanjaro software could be a dependable tool for evaluation of bone healing of alveolar clefts. This increase of bone density of the grafted cleft site may be attributed to the intermingled processes of rapid revascularization of intramembranous symphyseal bone graft and the bone theory phases (phase I&II) of bone graft healing, Axhausen(1956).

These radiographic results are in accordance with Weijs et al in 2010, who conducted a study for secondary closure of alveolar cleft using mandibular symphyseal bone graft and β-tricalcium phosphate. Radiographs were taken immediate and 1 year postoperative and revealed adequate bone formation with minimal bone resorption,.

Furthermore, the very high positive correlation seen in the present study between bone density values measured by DIGORA and IDRISI techniques at different time intervals; indicate that IDRISI Kilimanjaro software is as much reliable as Digora technique for densitometric analysis of the alveolar cleft area. These results are coincide with the results of a study was conducted by El hayes et al., in 2012 who conclude that IDRISI Kilimanjaro software could prove its validity and reliability in densitometric analysis around dental implants for assessment of osseointegration when it is calibrated with CBCT and it is as accurate as CBCT for this purpose. This is in agreement also with Salah et al., in 2010 who used IDRISI Kilimanjaro software for radiodensitometric analysis along mandibular fracture treated with low level laser therapy and found that IDRISI software is an accurate and valid method, Salah et al.,(2010).

From the previous findings, it was concluded that IDRISI Kilimanjaro software is a reliable and valid alternative method to DIGORA for densitometric analysis of the alveolar cleft area.

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