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Original article

Role of single photon emission computerised tomography in evaluating osseointegration of indigenous DRDO implants: An in vivo study

Col S.K. Bhandari^{a,*}, Anupam Mondal^b^a Dy Commandant & Classified Specialist (Maxillofacial Surgery), CMDC (SC), Pune-40, India^b Scientist 'F', Head, Division of PET Imaging, INMAS, Delhi 110054, India

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ABSTRACT

Background: A study of first indigenous titanium dental implant developed by DRDO was undertaken at INMAS, Delhi. The aim was to establish the time taken for osseointegration, along with objectives to define the time of implant loading and compare the osseointegration of indigenous dental implants with already established dental implant systems.

Methods: 21 subjects rehabilitated using 39 indigenous dental implants were evaluated by bone SPECT before implantation and at regular intervals towards establishing the aim and objectives.

Results: The rise followed by fall in Osteoblastic activity indicates the postoperative physiologic changes, which peaked at 2 weeks (mean) post-implantation and falls off to pre-implantation levels in 12 weeks (mean) indicating completion of osseointegration, healing and time of loading.

Conclusion: It can be summarized that the Osteoblastic activity of indigenous dental implants completes within three months, which can be taken as the time required for complete healing/osseointegration and loading the implants. On comparison with the available data of already established implants the figures appear similar, indicating indigenous implants to be similar in biologic behaviour.

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Introduction

A study was undertaken after due ethical committee approval with the aim to establish the time period for osseointegration of first indigenously developed DRDO dental implant system, along with objectives to define the time of implant loading i.e. final rehabilitation of the subjects and compare the physiologic process of osseointegration with already established dental

implant systems using three phase bone scan, Single Photon Emission Computerized Tomography (SPECT) study. The study was designed as the traditionally practiced procedures of evaluation i.e. clinical judgements, radiological evaluation and tomographic evaluation can only give two dimensional quantification of the defect, can facilitate quantification of bony changes or give morphologic bony changes; but definitely fails to detect dynamics of osteoblastic activity.^{1–5}

* Corresponding author.

E-mail address: kumarsdel@gmail.com (S.K. Bhandari).

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In three phase bone scan with SPECT study, bone seeking pharmaceutical agent methylene di-phosphonic acid (MDP) added to gamma photon emitting radionuclide Technetium 99 (15–20) is injected by intravenous route resulting in distribution of radioactivity in all three planes and phases (vascular, blood pool and bone phase) including the area of interest which can be detected using gamma camera. The technique utilizes radionuclide tracer targeted imaging based on detection of gamma rays emitted by the radionuclide when embedded in biological specific compounds after intravenous administration. The radionuclide emits gamma rays which can be detected singularly/individually by collimation technique using gamma camera, thus known as “single photon imaging”. The said imaging technique maps the three dimensional structures into two dimensional images, the third dimension is incorporated by tomography technique. These multiple projections are compiled using image reconstruction software to reconstruct the three dimensional image of the area of interest/object (thus SPECT).^{6,7} This provides an additional refinement to planer imaging and permits accurate quantification by removing regions not of clinical interest. This technique enables to obtain a three dimensional representation of distribution of radioactivity within area/organ of interest conforming greater diagnostic accuracy, volumetric measurements, morphologic details and details of physiologic activity by accurate volumetric measurements i.e. by quantizing the distribution of radioactivity per unit volume of tissue,⁸ which helps in providing accurate measurement of quantitative physiologic events like osteoblastic activity and healing.

This article describes SPECT analysis to study the dynamic bony changes post-implantation, using osteoblastic activity index to assess the physiologic activity around the implants. A protocol has been outlined to evaluate the progress of healing process, define time taken for complete healing and also time of loading of these dental implants.

Materials & methods

Twenty one volunteers with age ranging from 17 to 84 years were taken up for the study for rehabilitation with implant retained prosthesis, the details of the patients along with the location of implants is as shown in Table 1. Thirty eight implants out of thirty nine showed excellent osseointegration, one implant (subject 5) in the series showed failure after seven days; the case was dropped out from the study. To avoid the variables effecting the study; patient selection was restricted to cases with no local and systemic factors influencing the healing process. Implants manufactured out of one metal type (titanium ASTM grade II) with stereotype design (i.e. surface treated, root form cylindrical with rectangular threads) was used, the selection of the implant size (i.e. diameter and length) was based on principles as laid down by Misch,⁹ for every patient all desired implants were placed in single sitting and to reduce the operator specific variable the surgical procedure was carried out by one single operator.

All the patients were taken up for study of osteoblastic activity five times starting seven days pre-implantation followed by 14th, 42nd, 56th and 84th day post-implantation. For the study 15 mCi technetium 99 MDP (methylene

Table 1 – Details of patients taken up for study (M = 18, F = 3, M:F = 6:1, Total subjects = 21, Total implants = 39).

Subject no.	Age	Sex	No. of implants	Position of implants
1	17	M	2	12,13
2	20	F	2	36,37
3	53	F	2	46,47
4	45	M	3	15,16,17
5	42	M	1	37
6	61	M	1	13
7	45	M	2	25,26
8	57	M	1	36
9	30	F	1	11
10	55	M	2	11,21
11	40	M	1	36
12	45	M	1	46
13	84	M	3	33,43,Midline symphysis
14	80	M	4	32,33,42,43
15	30	M	4	33,35,23,25
16	70	M	4	25,26,36,37
17	30	M	1	11
18	57	M	1	36
19	56	M	1	26
20	58	M	1	23
21	21	M	1	34

di-phosphonate) was injected intravenously. A three dimensional representation was achieved using Dual Head SPECT GE camera with large field of view (LFOV) and low energy high resolution (LEHR) collimator. Anterior and lateral images (Fig. 1) of the area of interest were taken post injection during blood pool phase i.e. after 10 min and skeletal phase i.e. after 3 h post injection. These cross-sectional images were

Fig. 1 – Image as acquired and processed under SPECT study, showing hot area as red (radioactivity) in the area of interest (37) with reading as 42.38 μ ci/unit as compared to control area showing reading of 23.51 μ ci/unit.

used to reconstruct the coronal images. The activity (pixel count) in the area of interest was compared with the activity in the skull (control). The Osteoblastic Activity Index (OAI)¹ was calculated by dividing average pixel count in the area of interest by average pixel count in the skull (control).

The values of OAI were calculated for each SPECT study, consolidated mean values are as shown in Table 2 and graphic plotted data of OAI vs. time was prepared (Fig. 2A & B). All the patients were also subjected to clinical examination using Misch implant mobility scale and intraoral periapical radiological examination⁹ during each visit, to clinically assess the success.

For the purpose of comparison with the already established implant systems the values of OAI as published in the literature^{1,10–13} were considered along with the name of the implant system/author and are tabulated in Table 3.

Results

The patients were subjected to clinical evaluation by subjecting them to implant mobility scale as described by Misch on 14th, 42nd, 56th, and 84th day post-implantation. The reading documented for all the individual tests was IM-0 i.e. showed absence of mobility with approximately 500 g of labiolingual force indicating successful osseointegration (except for subject 5 who was dropped out for study showed reading of IM-2 on 14th day followed by IM-3 thereafter). The radiologic evaluation revealed no presence of radiolucency (except subject 5) between the implant surface and the bone suggesting successful osseointegration.

Table 2 – Consolidated and mean values of OAI at – 7, 0, 14, 24, 56 and 84 days of Subjects under study.

Subject no	Day				
	7th	14th	42nd	56th	84th
1	1.4	3	2.9	1.6	1.5
2	1.8	3	2.8	1.9	1
3	1.9	2.9	2.8	2.1	1.8
4	2.2	3.1	2.9	2.4	2
5	1.4	1.9	1	1.4	1.6
6	2.2	3.3	2.9	2.4	2.2
7	2.5	3.7	3	2.7	2.3
8	2.5	3.8	3.2	2.7	2.5
9	2.7	3.9	3.3	2.9	2.7
10	2.8	4	3.3	2.9	2.7
11	2.8	5.3	3.3	2.9	2.8
12	2.9	5.5	3.6	2.9	3
13	2.9	5.4	3.7	3	3
14	2.9	5.4	3.8	3	2.9
15	3	5.5	4	3	3.2
16	3.1	5.5	4	3.3	3.3
17	3.2	5.6	4	3.2	3.2
18	3.2	5.8	4.8	3.5	3.2
19	3.3	5.8	5	3.5	3.4
20	4	6	5.2	5	4
21	4.3	7	5.5	5	4.5
Mean (Excluding Sub-5)	2.78	4.33	3.70	2.99	2.76

The calculated values of OAI have been demonstrated in this study in normal edentulous jaw bone before and sequentially post-implantation using indigenous DRDO dental implants till healing, indicating the accurate serial quantification of osteoblastic activity. The result of OAI is as complied in Table 2 and in the graphs as shown in Fig. 2. It is evident from the plotted graphs that the OAI vs. time shows three distinct stages in relation to preloading value of activity. Stage one shows a slow rise in osteoblastic activity, stage two shows peak osteoblastic activity after about 14 days post-implantation and in stage three a steady decline in the osteoblastic activity was seen reaching to pre-implant OAI level in about three months post-implantation suggesting the complete healing/osseointegration and time of loading. All the selected subjects were rehabilitated with implant retained fixed prosthesis after complete osseointegration was achieved i.e. after three months of implant placement.

In comparison to SPECT studies with other implant systems as shown in Table 3, DRDO dental implant system proved equally good and at times better as far as time taken for healing, fall off OAI to pre-implants' levels or wait period for loading is concerned.

Discussion

Literature on evaluation of peri-implant bony changes and study of osseointegration shows use of RFA, histological and histomorphometric methods, radiographs, tomography, scintigraphy and SPECT studies.^{10–13} The reliability of RFA to predict implant stability and to determine loading time remains questionable.¹⁴ Use of histological and histomorphometric methods^{15,16} for the purpose requires sacrifice of the area of interest along with the implant. A radiologic study provides only two dimensional morphological quantification of the area of interest in one single plane.¹⁷ Tomography can provide quantification of the morphologic changes in all the three planes but fails to provide information about physiologic activity.⁹ Scintigraphy can reflect physiologic activities in one plane,⁴ with an inherent limitation of accurate quantitative analysis attributed to distortion and superimposition of undesirable anatomic structures; whereas SPECT studies provide additional refinement when compared to scintigraphy as it provides accurate qualitative and quantitative analysis,^{5,18} but with limitations of additional radiation exposure and the increased cost.¹⁹

Meidan Z et al¹⁰ in 1994 used scintigraphy to evaluate the peri-implant tissue. They used the term Bone Scan Index (BSI) to reflect metabolic activity in the peri-implant area. The mean BSI using these implants reaches peak in 2.5 weeks and gradually declines to pre-surgical values after 16 weeks, whereas in our study it was 2 weeks followed by 12 weeks (mean) respectively. The variation in complete osseointegration of different implant system can be attributed to the type of metal used by different manufacturers. The study clearly indicates that the indigenous implants developed by INMAS (DRDO) can be taken up for loading after twelve weeks, as against the Israel implant system which can be loaded after 16 weeks.

Fig. 2 – The graphic plotted data OAI vs. time. (A) Graphical plotted data: osteoblastic activity (Y-Axis) vs. time (X-Axis) of subjects under study, showing gradual fall of OAI to pre-implant values in 12 weeks time (approx) with indigenous DRDO implants. (B) Graphical plotted data: mean values of OAI (Y-Axis) vs. time (X-Axis) of subjects under study with indigenous DRDO dental implants.

Cervelliv et al¹¹ in 1997 studied SPECT procedures to evaluate osseointegration dynamics in 25 patients, who were taken up for intraoral and extraoral implantology for various prostheses. In the publication, the radiation emission corresponds with the OAI values of our implant system. Looking at the results and the discussion, it is evident that the metal used is similar to commercially pure titanium grade II used by indigenous DRDO implant system. In discussion, the author also says that the nuclear medicine methods in addition to traditional radiological procedures introduce new possibilities,

although this is still in clinical experimentation phase for the purpose of evaluation of inserted implant prognosis, which has been attempted in this study.

Schliephake Hand Berding G in 1998¹² evaluated the healing of onlay grafts to edentulous jaws in conjunction with osseointegrated implants using SPECT in 24 patients, who had received 26 full arch onlay grafts for augmentation with secondary placement of implants 21.4 weeks after grafting. The author has not specified the trade name of the implant system used; the quality of the metal used and also has not specified the exact timing of SPECT study. In discussion the author documents that there was significant decrease in tracer uptake (OAI) during graft healing, followed by a significant increase after implant placement and subsequent decrease in implant healing which corresponds with any of the similar studies. However the study cannot be compared with our or any other study, as the author has not provided any reading of tracer accumulation (OAI). In the study as quoted by the author, three patients showed infection and partial necrosis of grafted bone which was detected by decrease in tracer accumulation as compared to patients with uneventful healing which is taken as inferior graft revascularization. Also fourteen implants in the study failed which also shows a reduced tracer accumulation after implant placement, which is similar to reading of single implant failure in our study.

Table 3 – Comparison of osteoblastic activity: peak and fall to base line (days) with various implant systems.

S. No	Implant system	No. of subjects	Peak OAI at weeks	Fall to base line (weeks)
1	DRDO	21	2	12
2	Israel implants (Median et al)	26	2–3	16
3	Italian implants (Cervelli V et al)	25	3	10
4	Astra tech implants (Khan et al)	5	4	16
5	German implants (Jamil et al)	24	3	8

With the aim to evaluate the healing of onlay grafts on edentulous jaws after tumour ablation in conjunction with osseointegrated implants Jamil M.U. et al¹³ conducted SPECT study. He examined a total of 24 patients with secondary implant placement 21.4 weeks after grafting. In discussion, the author mentions that there is a significant decrease in tracer uptake during the graft healing. Which increased significantly after implant placement and subsequently decreased during implant healing. As the values of osteoblastic activity and the time of SPECT study is not provided by the author, the study cannot be compared with our or any other study; though the general trend in rise and fall of the OAI commensurate with our study. The author documents that in patients with compromised healing, the tracer uptake (OAI) was significantly lower as compared with patients with uneventful healing; sequential bone scintigraphy and bone SPECT have the prognostic potential to detect area of inferior bone revascularization leading to graft failure or failure in osseointegration of implants and also documents that only bone SPECT allows exact localization of areas with complicated/compromised healing.

Khan et al in 2000¹ evaluated the integration process in Astra Tech, Swedish endo-osseous dental implants using SPECT. The general pattern of increase and decrease in OAI is similar except that the OAI comes down to near normal values in using Indigenous DRDO implant system in 3 months as compared to 4 months in the study, which indicates that in best of bony conditions, the indigenous implant can be loaded in 12 weeks time as compared to 16 weeks in using Astra Tech Implants.

Number of factors/variables influences the initial successful osseointegration of dental implants.¹ These includes biologic bone type, type of metal used and extent of injury caused during surgical placement of these implants; though it is understood that it is difficult to quantify relative contributions of each component towards healing and osseointegration. In our series as the pre-implant SPECT values of osteoblastic activity involving the area of interest for each individual subject showed normal and consistent reading, we can assume that the healing/osseointegration/metabolic activity would not have varied in the selected patients during the study, thus justifying achieving the aim and the results of the study.

In the study, the values of OAI have been demonstrated before implantation and sequentially post-implantation, indicating values along with objectivity of the method by actual serial quantification of OAI. The graphic plotted data clearly indicates OAI returns to pre-implant levels in approximately three months time post-implantation suggesting mean osseointegration and healing time to be three months, which is also considered to be time of loading. The study also indicates that osteointegration and time of loading of other implant systems to be similar (Table 3) or near similar to our findings. The variations (Table 3) can be attributed to the fact that the process of osseointegration is independent of design and depends on the specific metabolic process of the bone in reaction to the quality of metal used.¹⁰ As all the documented studies have followed strict patient selection protocols to exclude variables influencing the metabolic process of osseointegration/healing and have considered the mean values of osteoblastic activity from a cross-section of patients

for their studies, we have no reason to disbelieve our comparative evaluation with other implant systems.

It can be summarized that the protocol of sequential SPECT imaging demonstrated along with the calculation of osteoblastic activity can provide an excellent model to study the progress of various graft/implants used for various reconstructions. Our study is rather more limited owing to limited sample size, use of only CP titanium ASTM grade II, consideration of mean OAI and also because of lack of available literature on the subject. To precisely define the time taken for osseointegration using different grades of titanium in various defined bone densities, it is proposed to design an experimental model involving significant number of subjects for rehabilitation with implants manufactured out of all commonly used bio acceptable titanium grades in all defined bone densities. The proposed study will precisely define the mean healing and the loading time of titanium dental implants in various permutation and combination of bone type and metal type for clinical application towards long term success of oral rehabilitation.

In conclusion the mean time required for osseointegration of first indigenous dental implant designed and manufactured by DRDO can be taken as twelve weeks, which can also be considered as time of loading of the implants and also it is as good as other implant systems available in the market considering the time required for complete osseointegration.

Conflicts of interest

All authors have none to declare.

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