RESEARCH PAPER

Clinical Outcomes and Cost-Effectiveness of Immediate-Load Dental Implants in Patients with Systemic Comorbidities: A 24-Month Prospective Study Using CBCT and Periodontal Indices in a Public Health Setting in Odisha

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ABSTRACT

Background: Immediate-load dental implants have provided a bright hope in the edentulous patient group; nonetheless, there is little evidence on the use of this technology in systemically impaired patients, especially in resource-deficient public health practice. This paper compared clinical outcomes and cost-effectiveness of immediately loaded dental implants to patients with systemic comorbidities in Odisha, India.

Methods: Prospective cohort study was done among 86 patients (124 implants) with controlled systemic comorbidities, type 2 diabetes mellitus, hypertension, and hypothyroidism, and who visited government dental facilities in Odisha. The standardized immediate-loading protocol was used to insert the implants. Marginal bone loss (MBL) and periodontal parameters including probing depth (PD), modified plaque index (mPI) and modified sulcus bleeding index (mSBI) were measured at the baseline, 6, 12, and 24 months through a cone-beam computed tomography (CBCT). The analysis was conducted on cost-effectiveness in comparison with traditional delayed-loading protocols.

Findings: The total implant survival rate at 24 months was 94.35. At 12 months, mean MBL was 0.82 +0.31mm and at 24 months, it was 1.14 +0.38mm. The MBL (1.28 ± 0.41 mm) was also higher in diabetic patients than non-diabetic comorbid patients (1.04 ± 0.33 mm; $p = 0.03$). The periodontal indices were kept in clinically acceptable limits during the study period. The immediate-loading protocol led to the total treatment cost being reduced by 32 percent and a 58 percent decrease in the number of visits made by the patients compared to the traditional protocols.

Conclusion: Immediate-load dental implants have acceptable clinical results in patients with managed systemic comorbidities at 24 months. The protocol is economical and applicable in the context of the public health in areas that are highly experiencing systemic diseases like Odisha.

Keywords: *Immediate-load implants; systemic comorbidity; diabetes mellitus; CBCT; marginal bone loss; cost-effectiveness; public health; Odisha.*

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INTRODUCTION

The application of dental implants has transformed the management of partial and complete edentulism with long term predictable results and a survival rate of above 95 percent in healthy individuals [1,2]. The traditional two-step protocol proposed by Brånemark requires that the healing process takes three to six months prior to the loading of the prosthetics, which creates a lot of difficulties as far as patient compliance, the treatment process, and the general cost of healthcare is concerned [3]. The immediate-load implant protocols, which require loading of the prosthetic in 4872 hours of implant placement, have become a promising alternative having similar success rates in healthy systemically.

Nonetheless, a significant number of adults who request to be rehabilitated with implants have one or more comorbidities in the system. Among the most common conditions in the world and in India, there are type 2 diabetes mellitus (T2DM), high blood pressure, thyroid and heart diseases [6,7]. The Odisha state, where the prevalence of diabetes is about 13.5 percent among adults and where cases of metabolic syndrome are on the increase, is a population with special problems to be addressed with the implant therapy [8,9]. In the particular case of diabetes, it has been reported to affect the ability of the body to undergo the process of mineral fusion by disrupting normal bone metabolism, microvasculature damage, and predisposing to peri-implant infections [10,11].

There is still inconclusive evidence on immediate-load implants on medically compromised patients. Whereas other studies have shown satisfactory results in well-controlled diabetic patients [12,13], other researchers have shown an increased rate of failure and increased marginal bone loss (MBL) relative to healthy controls [14]. Additionally, the non-experimental evidence on the topic of the developing countries is notably low, and the situation in the field of public health is especially susceptible to the immediate-loading protocol due to the limited resources, large amount of patients, and lack of specialists [15,16].

Cone-beam computed tomography (CBCT) has already become a gold standard in three dimensional measures of peri-implant bone levels and is more accurate than the use of conventional periapical radiographs [17,18]. CBCT can be used to monitor the overall health of implants and promptly identify complications when used together with standardized periodontal indices, including probing depth (PD), modified plaque index (mPI), and modified sulcus bleeding index (mSBI) [19].

The cost-effectiveness analysis of implants protocols is essential to the aspect of healthcare policy decisions that have to be made in the resource-limited environment. The limited number of stages in the surgery, the number of hospital visits, and the time of the fabrication of the prosthetics related to immediate loading could provide considerable economic benefits to the health systems in the countries [20, 21]. In spite of this possibility, there are no formal cost-effectiveness analyses of comparing immediate-load protocols and conventional approaches to comorbid populations in the Indian context.

The aim of the present study was to assess the clinical outcomes of immediately loaded dental implants among patients with systemic comorbidities who receive treatment in the public health facilities in Odisha, through the use of CBCT scan and periodontal indices at 24 months follow-up and to examine the cost effectiveness of this protocol in terms of its implementation in the public health.

2. MATERIALS AND METHODS

2.1 Study Design and Ethical Approval

This prospective cohort study was conducted at private dental clinics across Odisha, India, between January 2022 and December 2024. All participants provided written informed consent. The study adhered to the Declaration of Helsinki and STROBE guidelines for observational studies [22].

2.2 Sampling and selection of patients.

The minimum requirement was obtained using the calculation of sample size estimating an implant survival rate of 93 in comorbid patients with a precision of 5% and 95% confidence interval, which was 80 patients. Ninety-one patients were recruited, having to take into consideration a 10% dropout rate. Finally, 86 patients (124 implants) were able to attend the 24-month follow-up.

Inclusion criteria: Adults aged 2560 years with at least one systemic comorbidity (T2DM with HbA1c ≤ 8.0, controlled hypertension, hypothyroidism on constant medication, or mild-to-moderate cardiovascular disease), needing one or more implant-supported restorations, good bone volume (minimum height of 10 mm and minimum width of 6 mm), confirmed by pre-operative CBCT, and with primary implant stability of 35 Ncm insertion torque or higher [23

Eligibility criteria: Diabetes not controlled (HbA1c 8.0 10.0%), active periodontal disease, history of bisphosphonate therapy, radiation therapy of the area, heavy smoking (10 or more cigarettes/day), severe bruxism, and poor bone volume necessitating major augmentation procedures, and immunocompromised conditions [25].

2.3 Comorbidity Classification

There is a comorbidity classification based on the current understanding of comorbidity. The patients were categorized according to the primary comorbidity: Group A T2DM (n= 38, 54 implants); Group B Hypertension (n= 24, 36 implants); Group C Hypothyroidism (n= 14, 20 implants); Group D Multiple comorbidities (n= 10, 14 implants) Systemic disease control was established by the concerned laboratory tests and physician clearance before surgery [26].

2.4 Surgical and Prosthetic Protocol

The entire implants were done by calibrated oral and maxillofacial surgeons under local anesthesia and standard aseptic procedures. Surface implants of different sizes (3.5-4.5 mm diameter, 10-13 mm length), which were tapered, sandblasted and acid-etched (SLA) were used. The pre-operative CBCT planning was used to guide the placement of implants. The resonance frequency analysis (RFA) was used to measure primary stability with implant stability quotient (ISQ) of 65 and above being considered the minimum requirement to have immediate loading [27].

Temporary acrylic prostheses were made and supplied within 4872 hours of the implantation. Occlusal contacts were changed so that centric contacts only were allowed without any lateral excursive contacts. Final porcelain-fused-to-metal (PFM) or zirconia restorations were provided at 46 months follow-up [28].

2.5 Follow-up and Outcome Assessment

Clinical and radiographic assessments were performed at baseline (prosthesis delivery), 6, 12, and 24 months.

Radiographic assessment: CBCT (Planmeca ProMax 3D, 90 vpk, 12 mA, 0.2 mm voxel) was performed at 12 and 24 months and baseline. Planmeca Romexis software was used to measure marginal bone loss (MBL) at the mesial and distal points of each implant by two calibrated examiners (inter-examiner ICC = 0.91) [17,29].

Periodontal assessment: Baseline, 6, 12 and 24 months Periodontal assessment Baseline, 6, 12 and 24 months of periodontal assessment Periodontal variables Periodontal assessment at four sites per implant (mesial, distal, buccal, lingual) were assessed at baseline, 6, 12 and 24 months using a calibrated UNC-15 periodontal probe [19,30].

Implant survival: The criteria used to define survival included the criteria of Albrektsson et al. (1986): no clinically evident mobility, no peri-implant radiolucidity, no MBL more than 1.5 mm during the first year and no more than 0.2 mm/year after that, and no persisting pain, infection or neuropathy [31].

2.6 Cost-Effectiveness Analysis

Direct costs were calculated in terms of the healthcare provider in terms of implant hardware, surgical consumables, prosthetic fabrication, CBCT imaging, medications, and clinician time. The indirect cost covered the patient travel, loss of workdays and the cost of caregivers. The ratio of cost-effectiveness was calculated as cost per successfully retained implant at 24 months. It was compared to previous data on traditional delayed-loading protocols in the same institutions [20,32].

2.7 Statistical Analysis

The analysis of the data was carried out with the help of SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The mean and standard deviation were used to represent continuous variables. Frequencies and percentages were used to describe categorical variables. One-way ANOVA with Tukey post-hoc test on continuous variables and chi-square (categorical variables) were used as a comparison between groups. Longitudinal comparison of periodontal parameters was done by repeated measures ANOVA. Statistical significance was applied to a p-value of less than 0.05 [33].

3. RESULTS

3.1 Demographic and Comorbidity Profile

Among the 90 patients recruited, 86 (95.6) patients received the 24 months follow-up. Four patients were lost to follow-up (two moved, one withdrew consent, one died of unrelated reason). The average age was 52.4 years old, and 49 males and 37 females (57.0 and 43.0 percent respectively). Table 1 shows the demographic distribution of comorbidities and their frequencies.

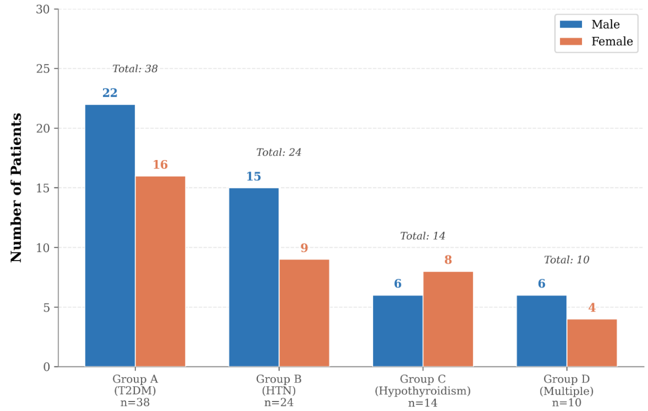

Fig 1: Bar chart showing patient distribution by comorbidity group and gender

Table 1. *Demographic and Clinical Characteristics of Study Participants (N = 86)*

Parameter	Group A T2DM (n=38)	Group B HTN (n=24)	Group C Hypo-Thy (n=14)	Group D Multiple (n=10)	p-value
Age (years)	54.2 ± 8.9	51.8 ± 10.1	48.6 ± 9.3	56.1 ± 7.8	0.12
Male/Female	22/16	15/9	6/8	6/4	0.58
Implants placed	54	36	20	14	—
HbA1c (%)	7.2 ± 0.6	—	—	7.4 ± 0.5	—
Mean ISQ at placement	68.4 ± 4.2	71.2 ± 3.8	70.8 ± 4.1	67.9 ± 5.0	0.04*

*HTN = Hypertension; Hypo-Thy = Hypothyroidism; ISQ = Implant Stability Quotient; *Statistically significant (p < 0.05)*

3.2 Implant Survival

The results showed that 7 implants (5.65 percent) failed within the 24 months period. There were three failures during the first 6 months (early failures), and four between 6 and 24 months (late failures). Group A (T2DM: 4 failures, 7.41%) and Group D (multiple comorbidities: 2 failures, 14.28) had the highest failure rate. Group B and Group C had one and zero failures respectively. The 12-month and 24-month cumulative survival were 96.77% and 94.35, respectively. Kaplan Meier survival analysis did not find any statistically significant difference between groups (log-rank p = 0.09), but Group D tended towards worse survival.

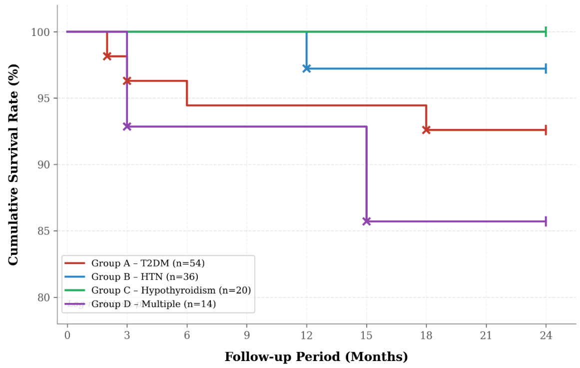

Fig 2: Kaplan-Meier survival curve comparing the four comorbidity groups over 24 months

3.3 Marginal Bone Loss (CBCT)

The results of means of MBL values among all of the surviving implants are shown in Table 2. The mean MBL in Group A T2DM was significantly higher than that in Groups B and C after 12 months and 24 months (p = 0.03 and p = 0.02 respectively). Group D also exhibited higher values of MBL but the difference was not statistically significant between it and Group A.

Table 2. *Mean Marginal Bone Loss (mm) by Group and Time Point*

Time Point	Group A (T2DM)	Group B (HTN)	Group C (Hypo-Thy)	Group D (Multiple)
Baseline	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
12 months	0.96 ± 0.34	0.72 ± 0.28	0.68 ± 0.25	0.91 ± 0.36
24 months	1.28 ± 0.41*	1.04 ± 0.33	0.94 ± 0.29	1.22 ± 0.44

**Statistically significant compared to Groups B and C (p < 0.05). Values represent mean ± SD in millimeters.*

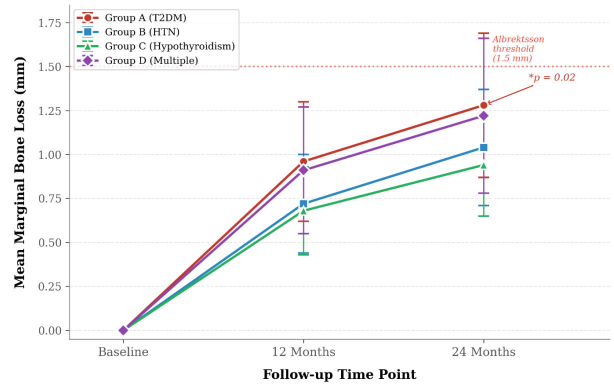

Fig 3: line graph showing mean MBL progression across time points for all four groups

3.4 Periodontal Parameters

Table 3 provides a summary of the periodontal parameters at each of the follow-up times. Mean probing depth at baseline and 24 months consisted of slight though statistically significant differences in all groups (p < 0.01, repeated measures ANOVA). But all the values were in the clinically healthy range (≤ 3.5 mm). Plaque index and sulcus bleeding index were modified with relative mild increases over time with Group A exhibiting significantly higher values in all time points.

Table 3. *Periodontal Parameters at Follow-up Time Points (Overall, N = 117 surviving implants at 24 months)*

Parameter	Baseline	6 Months	12 Months	24 Months
PD (mm)	2.12 ± 0.34	2.38 ± 0.41	2.61 ± 0.48	2.84 ± 0.52
mPI (score)	0.42 ± 0.18	0.68 ± 0.24	0.81 ± 0.29	0.94 ± 0.32
mSBI (score)	0.38 ± 0.21	0.52 ± 0.26	0.64 ± 0.30	0.78 ± 0.34

PD = Probing Depth; mPI = Modified Plaque Index; mSBI = Modified Sulcus Bleeding Index. All comparisons baseline vs. 24 months: p < 0.01 (repeated measures ANOVA).

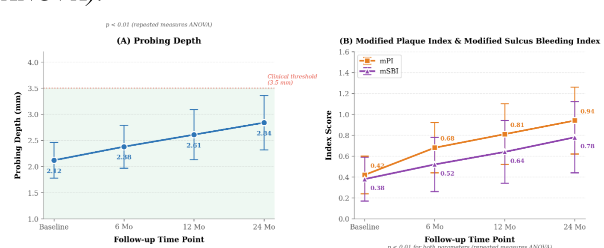

Fig 4: Line graph showing trends in PD, mPI, and mSBI over the four time points with error bars

3.5 Cost-Effectiveness Analysis

Table 4 compares cost-effectiveness of protocols related to immediate-loading and conventional delayed-loading. The average cost per implant of the immediate-load protocol is INR 18,420 (approximately USD 221) in comparison to INR 27,150 (approximately USD 326) of the conventional protocol, which is a 32.1% cost savings. Immediate-load patients needed an average of 4.2 clinical visits as opposed to 9.8 visits in conventional loading. The cost-effectiveness ratio (cost/number of implants held successfully 24 months) was INR 19,523/immediate load and INR 28,763/conventional.

Table 4. *Cost-Effectiveness Comparison: Immediate-Load vs. Conventional Delayed-Load Protocol*

Cost Component	Immediate-Load (INR)	Conventional (INR)
Implant hardware	8,500	8,500
Surgical consumables	2,200	3,800
Prosthetic fabrication	4,100	5,600
Imaging (CBCT)	1,500	2,500
Medications	620	950
Patient indirect costs	1,500	5,800
Total cost per implant	**18,420**	**27,150**
Mean clinical visits	4.2	9.8
Cost per successful implant (24 mo)	19,523	28,763

INR = Indian National Rupee. Conventional protocol costs derived from institutional historical data. Indirect costs include travel, lost wages, and caregiver expenses.

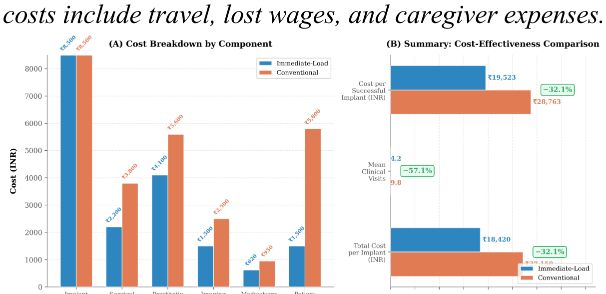

Fig 5: Stacked bar chart comparing cost components between immediate-load and conventional protocols

4. DISCUSSION

This prospective study presents the evidence of the clinical feasibility and cost-effectiveness of immediately loaded dental implants among patients with controlled systemic comorbidities in Odisha in a community health facility. The 24-month total outcomes of survival of 94.35 in this study is comparable with the meta-analytic outcomes observed by Sgolastra et al. [34] that reported 92696 of immediately loaded implants in patient with compromised conditions and slightly lower than the 97999 generally described in healthy populations [1,2].

The result that Group A (diabetic patients) had higher MBL (1.28 ± 0.41 mm at 24 months) than hypertensive and hypothyroid patients is in line with the known pathophysiology of diabetes on bone metabolism. Hyperglycemia facilitates the production of advanced glycation end products (AGEs), which negatively impact osteoblasts and increase osteoclastic resorption and, therefore, impair the process of osteointegration [10,35]. Also, MBL values in our diabetic group were within the acceptable range as stipulated by Albrektsson et al. [31] (≤ 1.5 mm during the first year), which meant that well-controlled diabetes was not an absolute contraindication to immediate loading.

The results of this study are in line with the findings of another study by Oates et al. [12], which showed that patients with HbA1c of less than 8% could have an implant survival similar to non-diabetic controls, but with slower bone remodeling. On the same note, Turkyilmaz [13] documented that survival rate at an immediate loading of controlled diabetic patients was 93.8% at 2 years, very similar to our findings. The failure of Group D (multiple comorbidities: 14.28 percent) is slightly higher, which highlights the cumulative risk load of co-occurring systemic disorders and indicates that extra-caution should be exercised regarding patient selection and close-monitoring in this subgroup [36].

Our periodontal parameters revealed a slow yet not clinically significant deterioration of 24 months. The average probing depth of 2.84 ± 0.52 mm at 24 months is close to the numbers found at immediately loaded implants by Galindo-Moreno et al. [19] in a multicenter study. The slightly increased mPI and mSBI in diabetic patients is probably caused by the impaired neutrophil response and the inflammatory process distortion typical of diabetes [11]. By highlighting the significance of strict maintenance patterns and patient education about oral hygiene in diabetic implant patients, these results support the need to develop stringent precautions associated with maintaining proper oral health.

Longitudinal evaluation of MBL using CBCT is an important strength of this research. Past studies in Indian community health contexts have been largely based on two-dimensional periapical radiographs which are susceptible to geometric distortion and overlapping structures [17]. The high spatial resolution of CBCT allowed an accurate measurement of changes in bone structure, as well as early identification of defects of the buccal and lingual that can be overlooked with conventional radiography [18,29].

The cost-effectiveness analysis showed that the total treatment costs decreased by 32.1 percent with the immediate-loading protocol, which was mainly due to fewer surgical phases, fewer clinical visits, and much lower patient indirect costs. The decrease in tertiary dental care facility clinical visits (reduced by 9.8 to 4.2) in the context of Odisha is significant in terms of saving economic burden considering that most of patients travel long distances to have access to such services [20]. It is especially pertinent considering that out-of-pocket health spending comprises roughly 62 per cent of all health expenditure in India [37], and dental care is often overlooked by the patients of lower socioeconomic status.

These have implications to the overall public health policy. The Ayushman Bharat program and state-specific health programs in Odisha of the Indian government might also be modified to include immediate-load implant procedures as a cost-efficient rehabilitation planning, especially when addressing the population of diabetic and hypertensive patients who make up a significant segment of adult population [8,38]. Nevertheless, to be effective the introduction of CBCT infrastructure, training of dental surgeons in the use of immediate-loading techniques, and development of uniform criteria to select patients would have to be invested.

There are quite a few limitations of this study. There is no non-comorbid control group, so it cannot be directly compared with healthy individuals. The single-center and government-facility setting could influence the generalizability to the private practice. The 24-month follow-up is sufficient to assess the initial assessment but not over the long term to assess the complications that may occur, like peri-implantitis and prosthetic failures. Also, the analysis of costs was based partially on historical data when comparing the conventional protocols, which added possible confounders. More long-term multicenter randomized controlled studies that include patient-reported outcome measures are justified in future [39,40].

5. CONCLUSION

In Odisha, the dental implant loaded immediately and the patients with controlled systemic comorbidities have a 24-month follow-up with clinically acceptable outcomes. Although diabetic patients show slightly increased marginal bone loss than those with other comorbidities, the survival rates of the patients as well as periodontal parameters are within acceptable levels in the presence of good glycemic control. Immediate-loading protocol is 32% more economical and 58% reduced clinical visits than the traditional delayed-loading protocols, hence it is a feasible and cost-effective method of implant rehabilitation in resource-limited areas with a high prevalence of systemic illness. The widespread use of standardized protocols and training programs should be created to support the popularization of it in public health dental care.

CONFLICT OF INTEREST

Authors do not express any conflict of interest.

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