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Optimizing Osseointegration in Periodontal Disease Patients: A Comparative Study of Treatment Protocols

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Abstract

Background: *In osseointegration, the body's tissues compete with pathogenic organisms to grow onto the implants through osteogenesis and contaminate, colonize, and form biofilm on the implant surface. As a result, the point where the implant and bone meet is where most problems related to implants arise. The purpose of this research is to improve osseointegration in individuals with periodontal disease who are receiving dental implants.*

Subjects and Methods: *Forty participants were split into three groups: advanced surgical techniques, antibiotic treatment, and implant surface treatment. X-rays, CT scans, and load measurements were used for examinations. The efficacy of osseointegration was assessed using pre-established criteria, such as no implant movement, no infection surrounding the implant, and no signs of disintegration on X-rays. Secondary outcome indicators included the length of implant loading, bone loss surrounding the implant, and any issues related to treatment or follow-up.*

Results: *The average age in the first, second and third groups was 40.2, 39.6 and 38.2 years respectively. Over five-year period, the first group's average bond strength was 62.51 n/m, the second group's 82.45 n/m, and the third group's 89.75 n/m. In the first group, the average percentage of bone loss around the implant was 71.66 n/m; in the second group 91.25 n/m; and in the third group 96.84 n/m.*

Conclusion: *This study Examined methods for improving osseointegration in periodontal disease patients after receiving dental implants. Comparing antibiotics alone with implant surface treatment and contemporary surgical techniques, the results show a significant improvement in osseointegration in the surgical techniques group.*

Keywords: Osseointegration, Periodontal Disease, Dental Implants, Antibiotics, Surface treatment, Gingivitis, Periodontitis.

Introduction

The loss or absence of a tooth generally alters the function of the oral and digestive systems [1]. As a part of oral alteration, the adjacent teeth shift to compensate for the missing tooth. Since it is not possible to clean the area, as a result, plaque accumulates and inflammation and secondary periodontal disease occur, thereby increasing the risk of tooth loss [2,3]. Additionally, the alveolar bone wears out as it is not receiving the required stimulation and weakens [4]. Dental implant technology was developed in the 1960s and became commercially available in the 1970s [5]. Osseointegration was first mentioned by Branemark, and the concept of using titanium implants in the body as materials for osseointegration was made [6, 7].

Dental implants are divided into one-stage implants and two-stage implants depending on whether or not they are exposed after implant insertion [8]. With or without flap the implant body is implanted in the bone. After 2–8 months of implantation, a procedure called second surgery is performed to expose the implant [9] then, healing screws are applied to the implant [10]. After 1-2 weeks, healing abutments are placed on the implants [11]. After a period of gingival healing ranging from 1 to 7 days, the impression is taken followed by fabrication and insertion of the prosthesis [12]. Dental implants are inserted into the alveolar bone in the maxilla or mandible of patients as tooth roots [12]. Because titanium has been found to have excellent biocompatibility, it is often used [13]. Dental implants that are installed in the bone are called implant bodies, and dental implants that are installed in the gum are called implant abutments or fixtures [14]. Most implants have the same shape, but the effects depend on the structure, shape, and surface treatment of the implant [15]. The surface area and surface roughness of the implant increase blood flow to the surface and contribute to rapid osseointegration [16]. This study aims to optimize the osseointegration in periodontal disease patients receiving dental implants.

Subjects and Methods

This study included a comparison between three techniques and protocols for improving osseointegration in gingivitis patients who have dental implants. These three techniques are the antibiotic treatment technique, the implant surface treatment technique, and the advanced surgical technique. The total number of participants was 40. We divided those patients into three groups: fifteen patients received antibiotic treatment in the first group, fifteen patients underwent implant surface treatment in the second group, and 10 patients underwent advanced surgical techniques in the third group. The study was conducted over five years of follow-up, from January 2019 to February 2024, at an advanced treatment center specializing in dental treatment. Laboratory examinations were performed on these patients using X-rays, CT scans (CBCT), and load measurements.

The main measure of interest: The effectiveness of osseointegration will be evaluated according to pre-defined criteria, including:

- There is no movement of the implant.
- There is no infection around the implant.
- No signs of disintegration appear on the X-ray.

This evaluation will take place during the final follow-up visit, which should occur at least five years after implant placement. Secondary outcome indicators include the duration of implant loading, the amount of bone loss around the implant, and any issues with treatment or follow-up.

Statistical Analysis

The study used Statistical Package for Social Science (SPSS), version 28. The findings were summarized using descriptive statistics, which included means, standard deviations, and percentages. The ANOVA analysis and linear correlation analysis was used to analyze the data, and the level of statistical significance was set at $p < 0.05$.

Results

The average age in the first group was 40.2 years with a standard deviation of 3.76 years, whereas in the second group, it was 39.6 years with a standard deviation of 5.01 years. The third group had an average age of 38.2 years and a standard deviation of 3.7 years. The percentage of females in the first group was 40%, 46.6% in the second group, and 50% in the third group. The percentage of smokers in the first group was 60%, the second group was 40%, and the third group was 40%. The percentage of Traditional implants was 70% in the first group, 84% in the second, and 85% in the third. Table (1) compares the averages of the demographic characteristics of the patients participating in the study.

Table 1: shows the demographic characteristics of the patients included in the study

Demographic Characteristics	group 1 (Antibiotic treatment) (n=15)	group 2 (Implant surface treatment) (n=15)	group 3 (Surgical treatment) (n=10)	F	P
Age					
Age: mean ± (SD)	40.2±3.76	39.60±5.01	38.20 ±3.70	$\chi 2$= 0.402	MCp= 1
Gender					
Sex, female: (%)	40%	46.60%	50%	2.30E-01	0.76
Smoking					
Smokers (%)	60%	40%	40%		
Non-Smokers (%)	40%	60%	60%	0.33	0.11
Implant type					
Traditional implants:(%)	70%	84%	85%		
Short cultivation:(%)	8.50%	9%	5%	0.01	0.44
Immediate implantation:(%)	20.50%	7%	11%		
Implant place					
Front:(%)	54%	50.50%	48%		
back:(%)	13%	14.50%	22%	1.00E-02	0.42
front &back:(%)	33%	35%	30%		

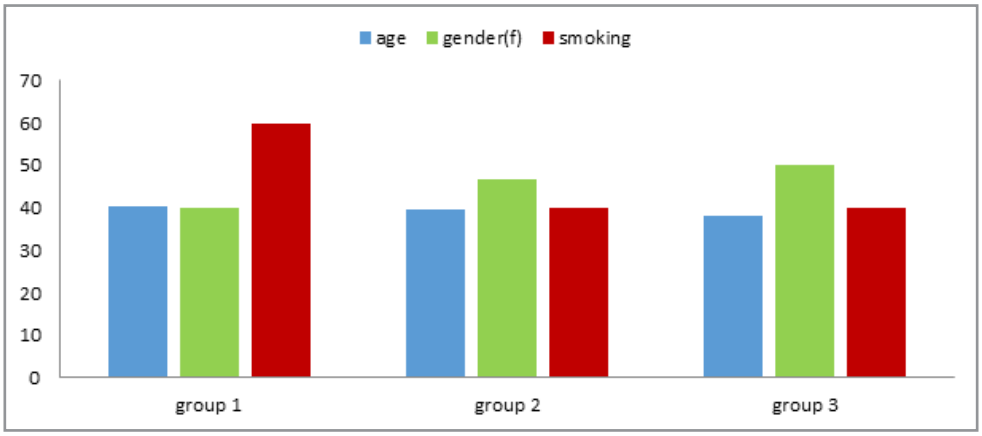

Figure 1: shows the demographic characteristics of the patients included in the study

The 5 years follow-up visits were divided into three stages, each lasting twenty months, for a total of sixty months. During the first twenty months, the average bond strength (n/m) in the first group was 62.51 (n/m) with a standard deviation of 3.78 (n/m), the second group was 82.45 (n/m) with a standard deviation of 3.08 (n/m), and the third group was 89.75 (n/m) with a standard deviation of 3.99.

The second twenty months showed an average percentage of bone loss around the implant in the first group was 71.66 (n/m), with a standard deviation of 3.05 (n/m), the second group 91 (n/m), with a standard deviation of 2.18(n/m), and the third group was 90(n/m), with a standard deviation of 4.37 (n/m).

In the last twenty months, the average percentage of bone loss around the implant in the first group was 74.77 (n/m), with a standard deviation of 2.04 (n/m), the second group was 94.25 (n/m), with a standard deviation of 1.78 (n/m), and the third group is 96.84 (n/m), with a standard deviation of 2.65 (n/m). It was also noticed that the p-values were less than 5% among all groups, even when comparing the change over the five years. We also noticed that the coefficient of variation is substantial, indicating that the data is statistically significant. Table (2) compares the three groups in terms of the average values of the bond's strength (n/m) over five years.

Table 2: Comparison between the three studied groups according to the strength of the bond (n/m)

Average of strength of the bond (n/m(	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
Duration 20 month					
Min. – Max.	49.0 – 65.0	82.0 – 99.0	83.0 – 96.0	1.03E+00	0.371
Mean ± SD.	62.51 ± 3.78	82.45 ± 3.08	89.75 ± 3.99		
Median (IQR)	63.10 (60.0 – 64.0)	84.10(82.0 – 85. 0)	84.0 (82.0 – 85. 0)		
Duration 40 month					
Min. – Max.	53.0 – 75.0	84.80 – 102.60	86.80 – 99.60	2.93	0.015
Mean ± SD.	71.66 ± 3.05	91 ± 2.18	90 ± 4.37		
Median (IQR)	73.21 (70.0 – 74.0)	86.33 (90.0 – 98.0)	89.10 (88 – 92.0)		
Duration 60 month					
Min. – Max.	60.50 – 77.50	87.70 – 107.20	91.0 – 109.0	0.444	< 0.001
Mean ± SD.	74.77 ± 2.04	94.25 ± 1.87	96.84 ± 2.65		
Median (IQR)	65.05(64 – 68)	96.70(94.0 – 100.0)	97.0 (98 – 104)		
p value	< *0.001	< *0.001	< *0.001		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA test, p: p value for comparing between the three studied groups, *: Statistically significant $p \leq 0.05$.

The 5 years follow-up visits were divided into three stages, each lasting twenty months, for a total of sixty months. During the first twenty months, the average bond strength (n/m) in the first group was 62.51 (n/m) with a standard deviation of 3.78 (n/m), the second group was 82.45 (n/m) with a standard deviation of 3.08 (n/m), and the third group was 89.75 (n/m) with a standard deviation of 3.99.

The second twenty months showed an average percentage of bone loss around the implant in the first group was 71.66 (n/m), with a standard deviation of 3.05 (n/m), the second group 91 (n/m), with a standard deviation of 2.18(n/m), and the third group was 90(n/m), with a standard deviation of 4.37 (n/m).

In the last twenty months, the average percentage of bone loss around the implant in the first group was 74.77 (n/m), with a standard deviation of 2.04 (n/m), the second group was 94.25 (n/m), with a standard deviation of 1.78 (n/m), and the third group is 96.84 (n/m), with a standard deviation of 2.65 (n/m). It was also noticed that the p-values were less than 5% among all groups, even when comparing the change over the five years. We also noticed that the coefficient of variation is substantial, indicating that the data is statistically significant. Table (2) compares the three groups in terms of the average values of the bond's strength (n/m) over five years.

Table 3: Comparison between the three studied groups according to the average of strength of the bond between the implant and the bone (n/m)

Average of bone loss around the implant (%)	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
Duration 20 month					
Min. – Max.	12.0 – 30.0	10.0 – 28.00	9.0 – 22.0	29.2	< 0.001
Mean ± SD.	12.0 ± 4.08	10.8 ± 2.66	10.2 ± 3.24		
Median (IQR)	12.20 (12.0 – 14.0)	10.10 (10.0 – 12.00)	11.0 (10.0 – 12.0)		
Duration 40 month					
Min. – Max.	10 .0– 25.0	10.0 – 24.0	8.0 – 20.0	31.3	< 0.001
Mean ± SD.	10 ± 5.81	9.5 ± 2.36	9.6 ± 2.78		
Median (IQR)	10.5 (10.0 – 11.0)	10.0 (10.0 – 11.0)	9.5 (9.0 – 10.0)		
Duration 60 month					
Min. – Max.	9.0 – 20.0	9.0 – 17.20	8 – 16.5	43.25	< 0.001
Mean ± SD.	9.3 ± 2.04	9.01 ± 3.21	8.2 ± 2.65		
Median (IQR)	9.5 (9.0 – 10.0)	9.0 (9.0 – 10.0)	8.0 (8.0 – 9.0)		
p	(<0.001*)	(<0.001*))	(<0.001*)		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA testp: p value for comparing between the three studied groups, *: Statistically significant $p \leq 0.05$

During the first 20 months, the first group had an average laxity (µM) of 42.51 (µM), with a standard deviation of 4.08 (µM). The second group had an average of 41.2 (µM), with a standard deviation of 2.66 (µM), and the third group had an average of 31.75 (µM), with a standard deviation of 3.99.

In the second 20 months, the average laxity (µM) in the first group was 35.2 (µM), with a standard deviation of 2.03 (µM), the second group 33.31 (µM), with a standard deviation of 2.77 (µM), and the third group 32.51 (µM), with a standard deviation of 4.12

Over the last 20 months, the average percentage of laxity (µM) in the first group was 28.32 (µM), with a standard deviation of 3.34 (µM), the second group was 20.13 (µM), with a standard deviation of 3.88 (µM), and the third group was 18 (µM), with a standard deviation of 3.65 (µM).

It was noted that the p-values were less than 5% across all groups, and even when comparing the change over five years. We also see that the coefficient of variation is substantial, indicating that the data is statistically significant. Table (4) compares the three groups' average laxity values (µM) over five years.

Table 4: Comparison between the three studied groups according to average of laxity (µM)

Average of laxity(µm(µM)	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
Duration 20 month					
Min. – Max.	39.0 – 55.0	29.0 – 46.0	25.0 – 38.0	20.23	< 0.001
Mean ± SD.	42.51 ± 3.94	41.20 ± 3.90	31.75 ± 3.99		
Median (IQR)	45.2 (44.0 – 48.0)	42.2 (44.0 – 46.0)	34.1 (33.0 – 36.0)		
Duration 40 month					
Min. – Max.	30.0 – 45.0	25.0 – 40.0	21.0 – 34.0	23.25	< 0.001

Mean ± SD.	35.20 ± 2.03	33.31 ± 2.77	32.51 ± 4.12		
Median (IQR)	36.2 (34.0 – 38.0)	34.17 (34.0 – 36.0)	32.01 (32.0 – 34.0)		
Duration 60 month					
Min. – Max.	26.0-32.0	18.0 – 28.0	15.0 – 29.0	44.04	< 0.001
Mean ± SD.	28.32 ± 3.34	20.13 ± 3.88	18 ± 3.65		
Median (IQR)	29.5 (30.0 – 32.0)	20.0 (19.00 – 21.0)	18.2.0 (18.0 – 24.0)		
p	(<0.001*)	(<0.001*)	(<0.001*)		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA test, p: p value for comparing between the three studied groups, *: Statistically significant $p \leq 0.05$

During the first twenty months, the average percentage of infections (%) in the first group was 2.9% with a standard deviation of (0.48%), the second group was 2.9% with a standard deviation of (0.54%), and the third group was 2.55% with a standard deviation of (0.38%). In the second twenty months, the average percentage of numbness in the first group was 2.5% with a standard deviation of (0.25%), the second group was 2.3% with a standard deviation of (0.87%), and the third group was 2.2% with a standard deviation of (0.78%). The average proportion of numbness in the first group over the last 20 months was 2.1%, with a standard deviation of (0.44%); the second group was 2% with a standard deviation of (0.23%); and the third group was 1.8% with a standard deviation of (0.65%). Furthermore, the results showed that the p-values were less than 5% across all groups, indicating that the data is statistically significant, even when comparing changes across five years. Furthermore, the coefficient of variation is substantial, indicating that the data is statistically significant. Table (5) compares the three groups' average results for the average percentage of infections (%) over the last five years.

Table 5: Comparison between the three studied groups according to average of infections (%)

Average of bone loss around the implant (%)	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
Duration 20 month					
Min. – Max.	2- 4.1	1.9 – 3.7	1.7 – 3.0	1.029	0.03
Mean ± SD.	2.9 ± 0.48	2.9 ± 0.54	2.55 ± 0.38		
Median (IQR)	2.9 (2.6 – 2.8)	2.8 (2.6 – 3.0)	2.6 (2.4 – 2.8)		
Duration 40 month					
Min. – Max.	2.3 – 3.4	1.8 – 3.1	1.7 – 2.8	1.025	0.025
Mean ± SD.	2.5 ± 0.25	2.3 ± 0.87	2.2 ± 0.78		
Median (IQR)	2.6 (2.4 – 2.8)	2.4 (2.3 – 2.6)	2.2 (2.0 – 2.4)		
Duration 60 month					
Min. – Max.	2.0 – 3.0	1.8 – 2.9	1.7 – 2.7	24.2	0.046
Mean ± SD.	2.1 ± 0.44	2.0 ± 0.23	1.8 ± 065		
Median (IQR)	65.05 (63.60 – 66.50)	64.70 (63.50 – 65.30)	64.0 (62.0 – 65.50)		
p	(<0.001*)	(<0.001*)	(<0.001*)–		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA test, p: p value for comparing between the three studied groups, *: Statistically significant $p \leq 0.05$

During the first twenty months, the first group experienced an average percentage of 26% numbness with a standard deviation of 0.78%, the second group 21.58% numbness with a standard deviation of 0.38%, and the third group 19.6% numbness with a standard deviation of 0.41%. For the next twenty months, the first group's average percentage of numbness was 22.1% with a standard deviation of 0.65 percent; the second group's average percentage was 20.1% with a standard deviation of 0.66%; and the third group's average percentage was 18.1% with a standard deviation of 0.78 percent. The first group's average percentage of numbness over in the last twenty months was 19.75%, with a standard deviation of 0.44%; the second group was 16.18% with a standard deviation of 0.85%; and the third group was 15.1% with a standard deviation of 0.65%. Even when comparing the change over five years, the p-values for all groups were less than 5%, indicating the data is statistically significant. Additionally, we noticed that the coefficient of variation has a high value, indicating the statistical significance of the data. A comparison of the three groups' average numbness (%) values over the five-years is presented in Table (6).

Table 6: Comparison between the three studied groups according to average of numbness (%)

Average of bone loss around the implant (%)	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
Duration 20 month					
Min. – Max.	14.4 – 36.0	11.0 – 30.0	10.08 – 24.64	4.22	0.025
Mean ± SD.	26 ± 0.78	21.58 ± 0.38	19.6 ± 4.1		
Median (IQR)	27.2 (26.0 – 30.0)	22.2 (20.0 – 24.0)	20.3 (20 – 22.0)		
Duration 40 month					
Min. – Max.	14.02 – 28.3	11.0 – 24.60	9.89 – 20.1	3.58	0.017
Mean ± SD.	22.2 ± 0.65	20.1 ± 0.66	18.01 ± 0.65		
Median (IQR)	24.4 (22.0 – 28.0)	20.1 (18.0 – 20.0)	18.1 (16.0 – 18.0)		
Duration 60 month					
Min. – Max.	12.50 – 25.50	9.50 – 18.50	9.0 – 17.0	4.42	0.002
Mean ± SD.	19.75 ± 0.44	16.18 ± 0.85	15.1 ± 0.65		
Median (IQR)	19.05 (18.0 – 20.0)	16.4 (16.0 – 18.0)	16.2 (16.0 – 17.0)		
p	(<0.001*)	(<0.001*)	(<0.001*)		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA test, p: p value for comparing between the three studied groups *: Statistically significant at $p \leq 0.05$

Table 7: Comparison between the three studied groups according to Total Optimizing Osseointegration (%)

Average of bone loss around the implant (%)	group 1 (Antibiotic treatment) (n=15)	group 2 (surface treatment) (n=15)	group 3 (surgical treatment) (n=10)	F	p
After 1 year					
Min. – Max.	5.80 – 8.4	6.2 – 8.0	6.5 – 9.0	11.29	<0.001
Mean ± SD.	6.3 ± 1.2	6.4 ± 2.11	6.6 ± 2.65		
Median (IQR)	6.4 (6.0 – 7.0)	6.6 (6.0 – 7.0)	6.6 (6.0 – 7.0)		
After 2 year					
Min. – Max.	8.80 – 9.90	8.5 – 11.2	8.8 – 11.5	10.35	<0.001
Mean ± SD.	8.9 ± 2.41	9.58 ± 2.08	10.01 ± 2.65		
Median (IQR)	9.01 (8.0 – 9.0)	10.10 (9.0 – 11.0)	10.2 (10.0 – 12.0)		
After 3 year					
Min. – Max.	9.2-12.1	10.1 – 12.6	9.5 – 12.9	19.5	<0.001
Mean ± SD.	10.51 ± 2.78	11.08 ± 2.32	12.01 ± 1.65		
Median (IQR)	11.10 (10.0 – 12.0)	11.6 (10.0 – 12.0)	12.0 (10.0 – 12.0)		
After4 year					
Min. – Max.	11.2 – 14.2	11.5 – 14.8	10.5 – 15.4	22.11	<0.001
Mean ± SD.	12.2 ± 2.18	13.2 ± 1.78	13.8 ± 2.2		
Median (IQR)	13.3. (12.0 – 14.0)	13.81 (12.0 – 14.0)	15.10 (14.0 – 15.0)		
After5 year					
Min. – Max.	12.5 – 16.8	13.6 – 18.6	14.8 – 20.2	11.54	<0.001
Mean ± SD.	14.2 ± 1.88	16.5 ± 2.08	19.5 ± 2.05		
Median (IQR)	15.1 (14.0 – 16.0	17.2 (16.0 – 18.0)	20.0 (18.0 – 20.0)		
p	(<0.001*)	(<0.001*)	(<0.001*)		

IQR: Inter quartile range, SD: Standard deviation, F: F for One way ANOVA test, p: p value for comparing between the three studied groups, *: Statistically significant $p \leq 0.05$

Table 7 presents the average improvement rate for each of the three groups. For the first year, the average improvement rate was 6.4% for the first group, with a standard deviation of 1.2; 6.4% for the second group, with a standard deviation of 2.11; and 6.6% for the third group, with an estimated standard deviation of 2.56.

With an estimated standard deviation of 2.41, the first group's average improvement rate in the second year was 8.9%, whereas the second group's average improvement rate was 9.58% and the estimated standard deviation was 2.08. In the third group, the average rate of improvement was 10.01% with an estimated standard deviation of 2.65.

In the third year, the average rate of improvement in the first group was 10.51%, with an estimated standard deviation of 2.78. In the second group, the average rate of improvement was 11.08.%. With an estimated standard deviation of 2.32, and in the third group, the average rate of improvement was 12.01% with an estimated standard deviation of 1.56.

In the fourth year, the first group's average rate of improvement was 12.2%, with an estimated standard deviation of 2.18, whereas the second group's average rate of improvement was 13.2% with an estimated standard deviation of 1.78. The third group's average rate of improvement was 13.8%, with an estimated standard deviation of 2.2.

In the fifth year, the first group's average rate of development was 14.2%, with an estimated standard deviation of 1.88, whereas the second group's average rate of development was 15.6% With an estimated standard deviation of 2.02. The average rate of improvement in the third group was 19.5%, with an estimated standard deviation of 2.08. The p-values were less than 5% across all groups, according to the results, which indicates that the data is statistically significant even when comparing changes over five-years. Additionally, we noticed that the coefficient of variation has a high value, indicating the statistical significance of the data.

The average percentage of overall improvement throughout the five years following dental implant procedures is displayed in Figure 2. Based on the improvement rate of around 20% after five years, the result indicates that the advanced surgical technique was the best protocol, with the implant surface treatment method coming in second; the improvement rate was roughly 17%. The third approach, which used antibiotics, was the least effective; the improvement rate was only 15%. The chart also shows that, except for the surgical method, where there was a distinct difference from the first year, the improvement rate was close throughout the first two years before a difference eventually emerged during the next three years.

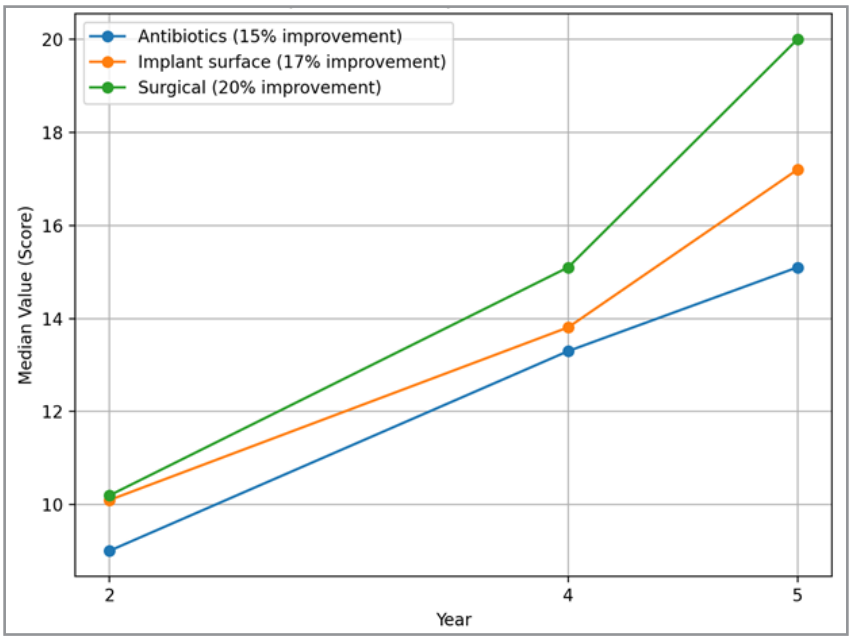

Figure 2: Comparison of groups across time points

Discussion

This study systematically evaluated the efficacy of three treatment protocols: antibiotic therapy, implant surface treatment, and advanced surgical techniques in optimizing osseointegration among patients with periodontal disease receiving dental implants. The results consistently favoured the advanced surgical protocol across multiple clinical parameters, offering compelling insights into best practices for implant therapy in compromised oral environments.

In situations where a dental implant is inserted with or without coexisting gingivitis or periodontitis, the reported impact on dental implant survival and bone levels is unknown [17].

For maximum implant longevity and the best potential aesthetic and functional result, early intervention is crucial in cases with possible compromised mucosa conditions [18].

In cases like this, mandatory initial treatment standardizes two-step implant therapy and jeopardizes a certain amount of time, during which the patient may require provisional implant placement if they have lost both functional and aesthetic function before receiving permanent treatment [19].

Being an advocate for their long-term health is the fundamental idea behind the treatment of patients receiving dental implants and implant-supported restorations [20].

One prerequisite is to be aware of any concurrent oral disease processes that may jeopardize their treatment outcomes [21].

Treatment procedures have been devised for managing periodontal patients with extensive tooth loss and implant failure [22].

Osseointegration failure is possible in patients with diabetes because glucose levels may alter bacteria around the implant site, leading to infections [23]. Periodontal diseases can also impede the healing of dental implants, potentially causing them to fail. [24]. The simplest and most prevalent type of periodontal disease is gingivitis, which is an inflammation of the gingiva surrounding the teeth [25]. It is brought on by the bacteria that is present in dental biofilm. It is readily treated by brushing, flossing, and getting regular checkups [26]. On the other hand, periodontitis is the destruction of bone and periodontal tissues as a result of an inflammatory response to pathogens like the bacteria found in dental biofilm and calculus materials in the oral environment [27]. Teeth's supporting structure may gradually deteriorate as a result of pathogens and host reactions that change and inflamed tissues like gingiva, periodontal ligaments, and alveolar bone [28]. Periodontal disease, which affects the gingiva and bone surrounding a tooth, is a disease that can affect an implant [29]. If a tooth is treated or lost because of periodontitis, bone change around the dental implant can happen, which is called peri-implantitis [30]. It is necessary to practice appropriate dental hygiene to attempt and minimize this bone loss. Additionally, smoking may aggravate peri-implantitis [31].

The percentage of females in the first group was 40; in the second group, the percentage of females was 46.6%; and in the third group, the percentage of females was 50%. Previous research showed that the prevalence of dental implants has significantly increased among both males and females aged 40 and older. In practically every category, the prevalence rates of dental implants were greater among females than they were among males. If a person was 40 years old or older, there was a gender difference in the likelihood of having dental implants, but there was no gender difference in the age range of 20 to 39 years old. This goes against the study of Schimmel et al., who stated that there is a notable increase in the occurrence of dental implants among individuals aged 40 and above, regardless of gender [31]. On the prevalence of implants among females, our results agreed with his. They claimed that in the majority of categories, women had higher prevalence rates than men. Females were 50% more likely than males to have dental implants in those 40 years or older, but there was no gender difference in the younger age group. Many smokers chose this route to replace their teeth despite multiple warnings regarding the systemic and local consequences of smoking on dental implants, and the success rate of these implants is lower compared to non-smokers [32, 33]. Bond strength averages during five-years are compared in three groups in Table 2. Over the first 20 months, the first group's average strength was the highest at 62.51 n/m, followed by the second group's 82.45 and the third group's 89.75. The first group experienced the greatest proportion of bone loss surrounding the implant in the second 20 months. Because the p-values were less than 5% a statistical significance was shown as indicated by the substantial coefficient of variation. Van Steenberghe reviewed the dental literature of 181 articles on Osseo integrated dental implants to examine the status of the teeth adjacent to the implants [34]. The data included six patient samples and five reports of individual patients. The most important information obtained was that there was no linear relationship between the reported percentages of different dental implant or peri-implant conditions and the number of planned or installed dental implants. Some authors reported that implant loss distributions ranging from more than 1 mm to 5 years in function fell to 0% at that point, but other research publications reported percentages of bone level losses that persisted up to 5 years in function [35]. In many studies, it was found that the overall survival rate was 97.17% during a research period of 10 years [36]. The studies reported success rates between 95% and 100%, but the inclusion criteria were different among them. Since there is a wide range of stress and strain distributions, it is difficult to characterize the stress and strain that dental implants create in the surrounding bone structure, even though they can restore masticatory function and aesthetics in edentulous cases [36].

Similar to this, the majority of studies concur that a set of atypical configurations needs to be carefully quantified. These include ideal bonds, complete bonds, and bond-free, which are three scenarios in which the implant is rigidly connected around the surrounding material without radial deformation between its specific contact, partial debonding, and complete debonding schemes, respectively. The lack of these constants and methodologies sets a wide range of variations that result in unstable studies [37]. These factors are due to the bone material's intrinsic heterogeneity, which results in diverse stress and strain distributions in the structure and around the surface of the dental implant [38].

The average numbness (%) values during five years are compared in three groups in Table 6. The largest proportion (19.7%), was possessed by the first group, followed by the second group (16.2%), and the final group was (15.1%). The significance of the data was shown by the p-value, which was less than 5%. The high degree of relevance was indicated by the substantial coefficient of variation. The p-value and coefficient of variation clearly show the statistical importance of the data.

Due to the complex anatomy, especially the proximity of the incisive canal to the alveolar crest and the emergence of the associated mental foramen surrounding the adjacent lateral incisor teeth, the majority of current clinical nerve injuries are caused [39]. Basic anatomical structures seem to be the most important consideration in the current calls for immediate implant creation; the lingual nerve branches of the inferior alveolar nerves, the mental foramina nerves, and the nearby incisive nerves are all in danger [36].

Antimicrobial prophylaxis is crucial in oral surgical procedures to prevent infections caused by bacteria from the patient's environment or hospitalization [40]. However, there was no consensus on the benefits, dosage, timing, and appropriate antibiotics [41]. The focus is on dental implant surgery and antibiotic prophylaxis, with most authors agreeing on the lack of evidence in favor of antibiotic prophylaxis [42]. However, good preoperative and postoperative rinses with chlorhexidine and regular oral hygiene are essential [43]. Dentists and implantologists must know about infection manifestations after endosseous implants to identify and treat complications [44]. The optimal protocol

was the advanced surgical method, with an improvement rate of about 20% after five years.

These findings align with literature suggesting that advanced surgical techniques, including guided bone regeneration and sinus lift procedures, enhance osseointegration by promoting vascularization and structural integration [45, 46, 47].

The role of implant placement timing is critical to successful osseointegration. Peitsinis et al. (2025) underscore that immediate implants, while efficient, are associated with esthetic compromise and higher complication risks if poorly selected. Early or delayed placement protocols allow for soft tissue maturation and ridge stability, leading to improved long-term outcomes [48]. This aligns with the current study's observation that advanced surgical techniques, often employed in delayed protocols, yield the most stable and predictable results.

In contrast, the antibiotic-only group demonstrated the least favorable outcomes. While infections were marginally controlled, the group experienced higher rates of bone loss, implant laxity, and numbness by the fifth year. These findings underscore the limitations of pharmacologic monotherapy in the absence of biomechanical or regenerative intervention, consistent with the conclusions of Salgado-Peralvo et al. 2023 [42] and Vippadapu et al. 2022 [40].

Implant surface treatment, though not as effective as surgical techniques, showed substantial improvements over antibiotics alone. The intermediate performance is supported by surface engineering literature indicating that increased roughness and hydrophilicity on titanium surfaces accelerate osteoblast attachment and bone deposition [15,16].

Abu Alfaraj et al. (2023) further emphasize the role of implant surface nanostructuring, biochemical coatings (e.g., vitamin D, melatonin), and tissue engineering approaches (PRF, MSCs, VEGF) in enhancing osseointegration. These adjuncts may complement surface modification and surgical techniques, representing future avenues for synergistic enhancement [49].

Conclusion

The evidence from this study confirms that advanced surgical protocols provide the most significant and sustained improvements in osseointegration among periodontal patients. While implant surface modifications provide moderate benefits, antibiotic-only treatments fall short of ensuring long-term implant success. Recent research indicates that personalized timing of implant placement, nanotechnology-enhanced surface designs, and regenerative therapies represent the future of optimized dental implantology. Future studies should focus on larger, randomized controlled trials incorporating systemic health variables, patient-reported outcomes, and cost-effectiveness analyses to guide clinical decision-making.

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Conflict of Interests

The authors declare no conflict of interest.

Ethics Approval

This study followed the Declaration of Helsinki and received ethical approval from the Faculty of Dentistry Research Ethics Committee (September 2024/ Reference Code: 0243).

Consent to Participate

Informed consent was obtained from all individual participants included in the study.

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