Assessment of Viewpoint and Opinions about Stress Distribution in Titanium Implants at Different Angulations Using Finite Element Analysis: An Original Research Study

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Abstract

Background and Aim: Dental implant has become popular nowadays however there are still some realistic issues are associated with it. Most of the failures of implants are seen after the loading of implants. This could be due to the uneven distribution of forces. Therefore, this study was conducted to evaluate the current viewpoint and opinions regarding stress distribution in Titanium implant with different inclination using finite element analysis.

Materials & Methods: This study was conducted on the results of pioneer researches in the last few decayed those published in literature worldwide. Authors included only the finite element analysis studied those performed for mandibular jaw only. Internet based tools like search engines, intellectual search bibliographic databases and textbooks were used. Authors explored the data until June 2024 using keywords and included 79 papers. Group I was having searches of 1975-1987. Group II was having searches of 1988-2000. Group III was having searches of 2001-2012 and group IV was having the search results of year 2013 onwards. Availability of data about Finite Element Analysis study per year, Finite Element Analysis study conducted for different angulations, their frequency, and number of studies attempted and their collective conclusions were taken into considerations to formulate the results.

Statistical Analysis & Results: Statistical analysis was completed by SPSS software. Group I confirmed only 4 studies and the p value was not significant with Chi Square Test (Pearson $\chi 2$) value 0.01. Group II had 14 studies and the p value was not significant with Chi Square Test (Pearson $\chi 2$) value 0.22. The level of significance (p value) was highly significant for the group II and III. Mean value was maximum noted for the 1975-1987, it was 0.938. It was minimum for 1988-2000, it was 0.582. Standard deviation was maximum noted for the 1975-1987, it was 0.839. It was minimum for 2013-, it was 0.103.

Conclusion: Within the limitations of the study, authors confirmed that there was a clear rising pattern of the Finite Element Modeling studies conducted on the mandible. However, most of the studies did not consider in detail about the possible effects of the changing angulations of implants on stress transfer. Authors also presume some long term future studies to be conducted to validate and confirm our results.

Keywords: Stress Distribution, Mandibular, Implant, Viewpoint, Failures, Bone, Finite Element Analysis

Introduction

As we all are aware that the placement of standard length dental implants in idea position is not clinically possible. This is particularly because of the closeness with the nearby anatomical structures like inferior alveolar nerve, mental nerve and maxillary sinus.[1,2] Surgeons are always confronted with these issues. These conditions literally force the operator to change the angulations of implant so as to avoid any possible puncture of the mentioned anatomical structures.[3,4,5] However, such changes are not always feasible and results in increased morbidity, elevated cost, and extended surgery timings. Many of the biomechanical studies including finite element analysis have revealed the change in stress transfer patterns with change of axial angulations of implants.[6,7] In most of the

instances, these angulations are not beneficial and results in ultimate failure of the implants.[8,9] Literature is overwhelmed with the finite element analysis/modeling studies conducted to explore the effects of change of axial angulations of implants on the stress distribution in alveolar bone.[10,11] Many researchers have postulated the use of short length implants to overcome the problems faced by angulated standard sized implants.[12,13] However, many recent clinical studied confirmed that length of the implant does not apparently affect the long term success and longevity of the implant and associated prosthesis.[2,3,14] Therefore, this study was conducted to evaluate the current viewpoint and opinions regarding stress distribution in Titanium implant with different inclination using finite element analysis (FEM).

Materials & Methods

Patients are more inclined towards the conservative approaches or therapies without involving normal teeth. Rehabilitation with implant retained fixed partial prosthesis has been proved as a viable option for partially edentulous patients. This study was based on the findings of pioneer researches in the last few decayed those published in renowned international journals worldwide. Authors constricted towards the finite element analysis studied those performed for mandibular jaw only. In most of the published data and studies, we noticed that clinicians had tried to place the implant parallel to the existing bone line of reference. The basic idea behind was to minimize the uneven distribution of stress along the bony trajectories and pathways in the jawbones. The search was a logical exploration wherein authors have used few keywords to mine the relevant data. Only journals and published books or reference books were refereed for data collection purpose. Explorations of biomedical literature are mainly reliant on internet-based online tools that support the uncomplicated recovery of biomedical information. Some of the notable internet based tools like search engines, intellectual search bibliographic databases and textbooks were used. Authors tried to mine the data until June 2024 using MeSH (Medical Subject Headings) based keywords such Stress distribution, Mandibular, Implant, Viewpoint, Failures, Bone, Finite Element Analysis. The exploration was limited to original researches, reviews, systematic researches and meta-analyses in different dental journals published over the last 50 years in English language only. A total of 236 articles were filtered initially however after careful assortment of their title, methodologies and results, this number was finally condensed to 79 articles. These explored data was grouped into four groups according to their year of publication. Group I was having searches of 1975-1987. Group II was having searches of 1988-2000. Group III was having searches of 2001-2012 and group IV was having the search results of year 2013 onwards. The studies those are based on data collection are highly imperative in getting comprehensive information. Availability of data about Finite Element Analysis study per year, Finite Element Analysis study conducted for different angulations, their frequency, and number of studies attempted and their collective conclusions were taken into considerations to formulate the results. Results thus obtained was tabulated and subjected to basic statistical analysis. P value less than 0.05 was considered significant ($p< 0.05$).

Statistical Analysis and Results

All the collected and predetermined factors and data were gathered and sent for statistical analysis using statistical software Statistical Package for the Social Sciences version 22 (IBM Inc., Armonk, New York, USA). The consequential data was subjected to relevant statistical tests to obtain p values, mean, standard deviation, chi- square test, standard error and 95% CI. P value less than 0.05 was considered significant ($p< 0.05$). Group I was showed exploration results of 1975-198, Group II showed exploration results of 1988-2000, Group III showed exploration results of 2001-2012 and group IV showed exploration results of year 2013- Till Date. Group I confirmed only 4 studies and the p value was not significant with Chi Square Test (Pearson $\chi 2$) value 0.01. Group II had 14 studies and the p value was not significant with Chi Square Test (Pearson $\chi 2$) value 0.22. Group III had also 19 studies and the p value was not significant with Chi Square Test (Pearson $\chi 2$) value 0.32. Group IV had 42 studies and the p value was significant with Chi Square Test (Pearson $\chi 2$) value 0.43. (Table 1-2 and Graph 1-2). Table 3 shows about the fundamental statistical explanations displaying mean, standard deviation, standard error, 95% coefficient of interval, Pearson Chi-Square Value and Level of Significance (p value). The level of significance (p value) was highly significant for the group II and III. Mean value was maximum noted for the 1975-1987, it was 0.938. It was minimum for 1988-2000, it was 0.582. Standard deviation was maximum noted for the 1975-1987, it was 0.839. It was minimum for 2013-, it was 0.103. Standard error was maximum noted for the 2001-2012, it was 0.802. It was minimum for 2013-, it was 0.035. Table 4 stated about the Evaluation amongst all studied Groups using one-way ANOVA. The p value was highly significant here. It was 0.002 for estimations made for Between Groups. Figure 1

illustrated about the Graphic illustration of Finite Element Modeling [FEM] for implant stress distribution. Figure 2 illustrated about the Graphic illustration of Finite Element Modeling [FEM] for implant stress distribution in mandible.

Table 1: Group based screening of explored papers (Group I to IV) with their Frequency, Standard Deviation and Standard Error

Group	Year Group	Frequency	Standard Deviation	Standard Error
I	1975-1987	4	0.829	0.009
II	1988-2000	14	0.039	0.082
III	2001-2012	19	0.853	0.329
IV	2013- Till Date	42	0.736	0.001*
***p<0.05 significant**				

Table 2: Group based screening of explored papers (Group I to IV) with Chi Square Test (Pearson $\chi 2$) and assessment of level of significances

Group	Year Range	Chi Square Test (Pearson $\chi 2$)	P value	Std. Deviation
I	1975-1987	0.01	0.33	1.933
II	1988-2000	0.22	0.65	1.453
III	2001-2012	0.32	0.34	0.548
IV	2013- Till Date	0.43	0.01*	1.746
***p<0.05 significant**				

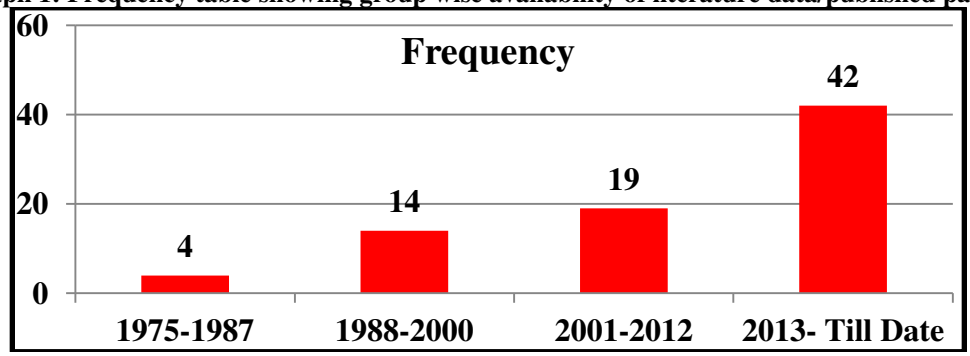
Table 3: Fundamental statistical explanations displaying mean, standard deviation, standard error, 95% coefficient of interval, Pearson Chi-Square Value and Level of Significance (p value)

Group	Year Range	Mean	Std. Dev.	Std. Err.	95% CI	Pearson Chi-Square Value	df	Level of Sig. (p value)
I	1975-1987	0.938	0.839	0.536	1.18	1.930	1.0	0.50
II	1988-2000	0.582	0.203	0.653	1.02	1.363	2.0	0.01*
III	2001-2012	0.603	0.453	0.802	1.35	2.534	1.0	0.02*
IV	2013- Till Date	0.712	0.103	0.035	1.13	1.930	1.0	0.90

Table 4: Evaluation amongst all studied Groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares ∑	Mean Sum of Squares m∑	F	Level of Sig. (p)
Between Groups	3	2.054	1.238	1.1	0.002*
Within Groups	18	2.039	0.125	-	
Cumulative	121.42	12.577	***p<0.05 significant**		

Graph 1: Frequency table showing group wise availability of literature data/published papers



Graph 2: P value table viewing group wise condition of level of significance

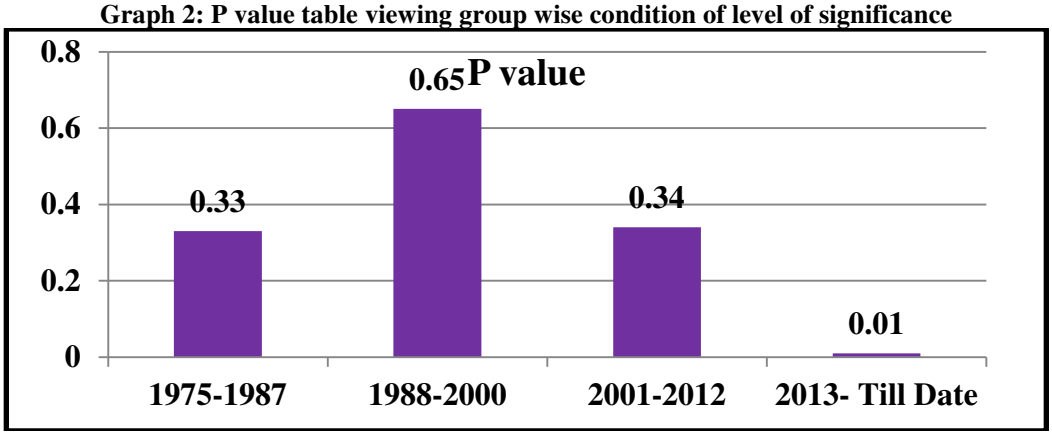


Figure 1: Graphic illustration of Finite Element Analysis/Modeling [FEM] for implant stress distribution

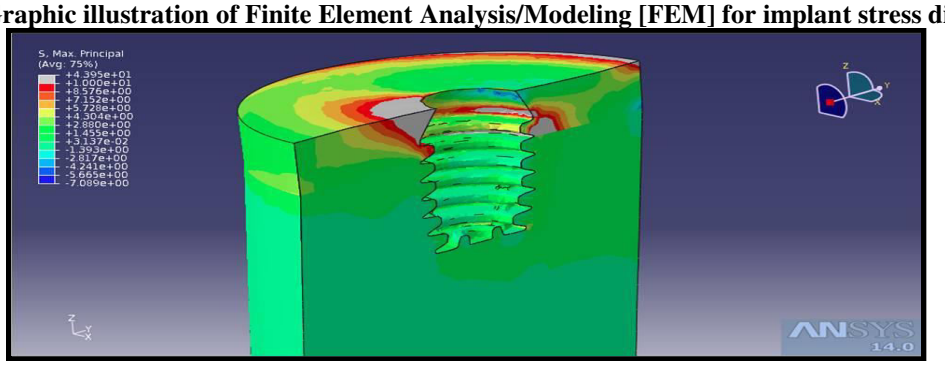
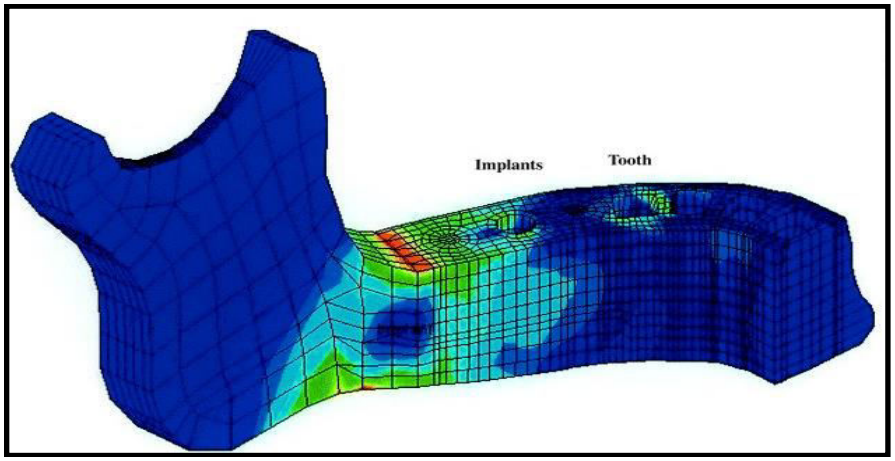


Figure 2: Graphic illustration of Finite Element Modeling [FEM] for implant stress distribution in mandible



Discussion

Bellini and associates studied in detail about finite element analysis of tilted versus non-tilted implant configurations in the edentulous maxilla. They also stated the deleterious effects of change of angulations of the implants on the stress distribution in lower jaw. These findings were in accordance with our study results.[15] Martini and coworkers have explored about the Straight and angulated abutments in platform

switching: Influence of loading on bone stress by three-dimensional finite element analysis. They conclude that increasing angulations poses the stresses out of the designated bony trajectories.[16] This was later on supported by several other researchers including Anitua and associates who experimented Retrospectively about the Transcrestal sinus lift using platelet concentrates in association to short implant placement.[17] Telleman and other pioneer workers had explored the systematic review of the prognosis of short (<10 mm) dental implants placed in the partially edentulous patient. Their findings were similar to our results and inferences.[18] Torres and colleagues have experimented about the Effect of platelet-rich plasma on sinus lifting. It was a randomized-controlled clinical trial wherein they find the negative effects of increasing angulations of titanium implants on mandibular jaw.[19] Esposito and other researchers have experimented about the Interventions for replacing missing teeth: Horizontal and vertical bone augmentation techniques for dental implant treatment. Their inferences were in accordance with our results hence our study was being supported by them.[20] Pieri and other pioneer researchers studied about the Short implants (6mm) vs. vertical bone augmentation and standard-length implants (>/=9mm) in atrophic posterior mandibles. They confirmed about the change in stress distribution pattern with the changing implant angulations.[21] Amato and other clinicians have clearly stated and studied about the immediate loading of fixed partial dental prostheses on extra-short and short implants in patients with severe atrophy of the posterior maxilla or mandible. It was and 4 years study wherein they showed the possible effects of implant angulations on their long term success.[22] Several other authors also studied and explored the similar effects and outcomes.[23-26]

Conclusion

Within the limitations of the study, authors noticed clear rising pattern of the Finite Element Modeling studies conducted on the mandible. Most of these studies were aimed to demonstrate the pattern of stress distribution and transfer towards underlying bone. This increasing pattern was potentially seen in the recent years. Authors also concluded that most of the published papers did not studied in detail about the potential effects of the changing angulations of implants on stress transfer. Many of the recent clinical studies have illustrated clear effects of angulations of stress patterns in bone. It is therefore highly imperative to include these critical factors in the upcoming Finite Element Modeling/analysis studies. This must be attempted not only for mandible but for both the jaws. Authors also assume some long term future studies to be conducted to authenticate and verify our results.

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