Retrospective Study To Identify Any Associations Between Clinician Training And Dental Implant Failure Rate Using MATLAB

Jyoti Sonkar BDS.,MPH, Qingzhao Yu PhD, Pooja Maney PhD., MS, A. Archontia Palaiologou DDS., MS
Department of Periodontics, Louisiana State University School of Dentistry

Introduction:

Dental implants are a commonly used and predictable option for the replacement of missing teeth. Implants are placed in the bone and eventually integrate with the surrounding bone within 8-10 weeks. An osseointegrated implant is non-mobile and asymptomatic with healthy peri-implant tissues surrounding it. Dental implants have very low failure rates, usually less than 5% (Carr et al, 2003). Despite the low failure rate, implant failures pose a significant problem for the clinician as well as the patient. Implant failures result in significant anatomic deficiencies that may require multiple surgical procedures in order to be corrected and are costly for both the dentist as well as the patient. Such a negative outcome can be a one hundred percent failure for the patient experiencing it. From a prosthodontist's standpoint implant failure can significantly alter future treatment options with implants and leave a patient with an only option of complete or partial dentures. From a periodontist and oral surgeon's standpoint it can result in increased number of procedures, bone loss and greater limitations in future possible treatment. This is costly to not only the surgeon but also the patient as a result of time spent out of work.

To help put the low percentage of failures in perspective it is important to note that based on American Academy of Implant Dentistry (AAID), about 30 million Americans have missing teeth and one tenth of them have implants in their mouth. The number of patients that have dental implants are expected to reach to half a million in the coming years. In 2006, about five and a half million implants were placed by US dentists. Even if the failure rate of these implants is only 2 percent, we can expect over 275,000 implant failures each year (AAID). With more and more dentists placing implants, it is evident that managing implant failures is a significant part of everyday dental practice and such failures pose a significant problem for both the patients and the dentists.

There are several known factors that contribute to implant failures; those include certain systemic conditions (i.e. smoking and diabetes) and local factors such as implant geometry, bone quality etc. Higher implant failure rates have been associated with poorly controlled diabetes (Salvi et al, 2008). Data suggests that smoking results in 3 fold increase of the risk of implant failure (Strietzel et al, 2014). Implants placed in augmented sites, have been shown to have five times the failure rate when compared to non-augmented sites (Carr et al, 2003). Moreover, higher failures rates have been found in posterior maxilla due to poor bone quality (Pabst et al, 2015). Implants with shorter length (<10 mm) and smaller diameter (<3.6 mm) have a higher potential of failure due to their inability to transmit occlusal forces in an appropriate manner often resulting in fracture or disintegration (Bergendal and Enngquist, 1998).

Implant failures can be classified as early or late. Early failures are caused due to insufficient or lack of osseointegration and may occur before the placement of the implant restorations. Previous research indicates that age, smoking, length of the implant and bone quality may be risk factors for early failures (Noda et al, 2015). Late failures occur after restoration of implants. It is usually associated with peri-implantitis due to poor oral hygiene. They may also share the same risk factors as early failures (Noda et al, 2015).

There are several factors that play a role in determining outcome of dental treatment. One such factor is level of experience of the surgeon. Previous studies have determined the existence of a relationship between the level of training and the clinical outcomes following certain periodontal procedures. Greater operator experience was associated with superior results in surgical procedures (Brayer et al, 1989). However, to our knowledge, no study has been done to determine any association of operator experience with the success rate of dental implants. Hence, this study intends to explore whether clinical training has any influence on implant outcome.

Should an association between level of training and implant failure be identified, such a finding could lead to curriculum changes in order to better address potential weaknesses. For example, recent changes in CODA standards for prosthodontics require that prosthodontics residents are trained in surgical implant placement with addition of only one month to the residency program. If the failure rates of the prosthodontics residents are higher than those of the surgical specialties (Periodontics or OMFS) that could indicate that a longer training period may be required. Similarly, if Periodontics residents present lower failure rates than OMFS for the same year of training that could indicate the need for further exploration of training differences between the two specialties in order to improve the success rates.

Several known risk factors have been associated with implant failures. However, there are no studies comparing the level of training of the residents and their expertise as a factor that could influence dental implant failure. Furthermore, there are no studies that compare implant failure rates between residents trained in different specialties. Hence, this study aims to identify any association between the types of clinician training on dental implant failure rates.

We hypothesize that the increased level of clinician training will significantly decrease the implant failure rates. We also hypothesize that the type of training provided by the department of Periodontics results in lower implants failure rates as compared to those of other specialties training.

The aim of this study is to identify any associations between predictor variables and dental implant failure rate among the residents in the departments of Periodontics, Prosthodontics, Oral Maxillofacial Surgery and General Practice Residency (GPR) at Louisiana State University, School of Dentistry.

This study is a retrospective examination of over 2000 implants placed that includes 150 implant failures reported at LSU School of Dentistry from January 1st 2011 up till December 31st 2015.

Material and Methods:

Patient records: Following IRB approval, dental records in Axium was reviewed from 2048 patients who received dental implants at LSU School of Dentistry from January 1st 2011 up till December 31st 2015. A database was created in Microsoft Excel.

- ***Inclusion criteria*:** Patients between 18 to 80 years of age whose records indicate that they received dental implants at LSU School of Dentistry from January 1st 2011 up till December 31st 2015.
- ***Exclusion criteria*:**
    - Patients whose implants presented with mobility at the time of placement (spinners)
    - Patients with incomplete records
    - Patients with no follow up for at least one year or more after implant placement

Determination of implant survival:

Implant survival is defined as absence of implant mobility and pain (Misch et al, 2008). Dental implant survival was based on comparison of radiographs taken at the time of implant placement and at one year recall.

The data collected from the patient records was categorized as:

- Patient demographics:
    - Age
    - Gender
- Implant and site characteristics:
    - Site
    - Graft
    - Sinus lift
    - Immediate versus delayed placement
    - Implant system
    - Implant length
    - Implant diameter

- Known confounding factors for implant failure: Smoking and Diabetes
- Study variables: Resident training and specialty department

Based on the inclusion and exclusion criteria, a total of 1486 implants were included in the study.

Each implant was determined to have been a success or a failure based on clinical absence of pain and mobility and radiographic absence of peri-apical radiolucency. The data on implant outcome was categorized by department of the resident that placed the implant and then by the level of residency training (e.g. second year or third year). This data included account for confounding variables (e.g. smoking, diabetes, implant location and implant characteristics).

Figure 1 and 2 present radiographic evidence of failing implants:

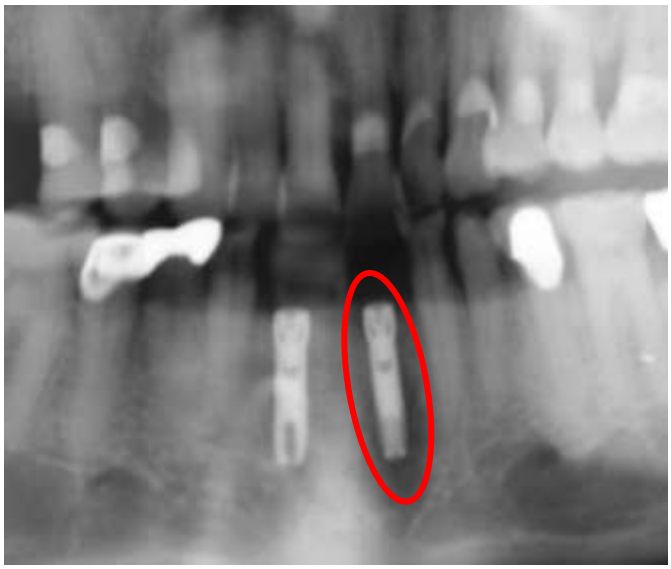

Figure 1. Implant at site of #23 shows periapical radiolucency

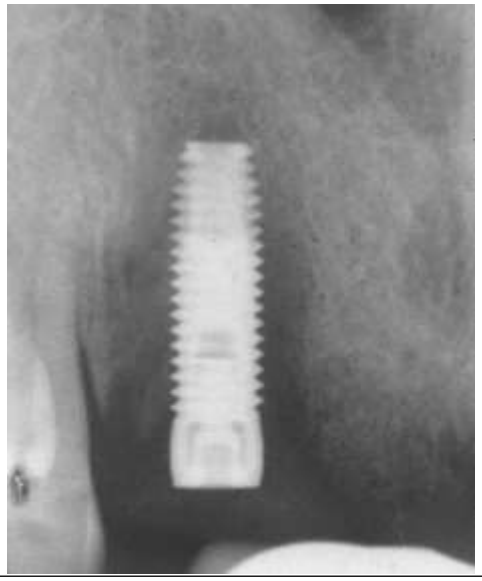

Figure 2. Implants shows surrounding loss

Statistical analysis:

For analysis, a statistical software Statistical and Machine Learning toolbox in MATLAB R2017a™ was used. Implant failure was selected as a dependent variable. Confounding variables includes age, gender, site, smoking, diabetes, hypertension, graft, sinus lift procedure, implant system, implant length, implant diameter, immediate versus delayed placement and past periodontal history. Study variables includes department and level of training. Variables were expressed in binary measures, 1- yes and 0- no to aid in analysis. Multiple excel sheets were prepared that included dependent variable along with each confounding variables/study variables and multilevel logistic regression was performed. Any the significant results were evaluated at P value of 0.05 error level.

Results:

A statistical analysis was conducted on the electronic health records of 1486 implants that were placed on 471 patients. 1378 (92.7%) implants had a successful outcome while 108 (7.3%) implants failed. There were 699 males and 787 females included in the study with the mean age of 59.65 years.

A multilevel logistic regression comparing the implant outcome to the variables was performed and clinician was used as a random variable in the model. It was concluded that discipline, implant system and year of training has a significant relationship with the outcome with p-values 0.0187, 0.0007 and 0.0541 respectively. The secondary analysis included comparison of the implant outcome to Discipline, Implant and Year of Training using each clinician as a random variable in the model. The findings obtained were considered significant at p-values 0.0024, 0.0004, <0.0001 respectively.

When adjusted for the level of training, the implant placement was compared amongst the residents in various years of training in Periodontics, third year residents in OMFS, and one-year fellowship training in Prosthodontics and GPR. For statistical analysis, the clinicians were stratified into groups based on the level of their clinical expertise.

Group 1 (Beginners): first-year residents of Periodontics department and the residents from Prosthodontic fellowship program

Group 2 (Intermediate): second-year residents from Periodontics department

Group 3 (Advanced): third-year residents from Periodontics and OMFS department

Group 4 (Highly Advanced): Faculties from the department of Periodontics

The overall implant survival rates for the level of training was significant- **Group 1 (90.13%), Group 2 (89.38%), Group 3 (94.20%), Group 4 (100%).**

The regression analysis comparing the discipline to implant outcome revealed significant statistical difference that comes from the overall implants survival rates which were- **GPR (97.3%), Periodontics (94.14%), Prosthodontics (91.48%), OMFS (89.64%).**

The implant outcomes amongst various implant systems were analyzed using each clinician as a random variable in the model. The significant statistical difference comes from implants success rate which were- **Straumann (96.8%), Zimmer (96.02%), Astra (95.58%), Nobel (92.69%), 3i (86.80%), Biohorizons (84.38%), Ankylos (89.28%), Keystone (50%).**

Discussion:

The study retrospectively examined 2437 implants that were placed at LSU School of Dentistry from January 1st 2011 up till December 31st 2015. Based on the inclusion and exclusion criteria, 1486 implants were included in the study. The objective was to understand whether the departmental training and resident experience along with previously established risk factors for implant failure affected the implant outcome. Several parameters such as age, gender, systemic conditions such as hypertension and diabetes, smoking, location, native bone versus grafted bone, one stage versus two stage implant placement and implant characteristics- implant length and diameter, resident training levels and overall department outcomes were analyzed. None of the previously established risk factor findings were found to be significantly associated with implant failures.

The overall survival rate of the endosseous implants placed in the post graduate departments was 92.7% (1378 out of 1486 implants placed). This finding is lower compared to the published findings of the survival rates in the

literature. When the implant survival rates were compared individually amongst the clinical departments, Periodontics performed well with the score of 94.14% (887 implants placed) in comparison with General Practice residency, 97.30% (37), Oral and Maxillofacial Surgery, 89.64% (386) and Prosthodontics, 91.48% (176). The survival rates were similar to the reports published in literature. Omran et al (2015) conducted a retrospective study in the graduate periodontics department and reported the survival rates for short endosseous implants to be 95.77%. Veitz-Kennan (2017) et al reported the implant survival rate from 91.67% to 100% in periodontally healthy patients whereas patients suffering from periodontitis had the lower range from 79.22%-100%. Also, in the university study conducted by Zupnik et al (2011) they found the endosseous implant success rate as 96.48% over 4 years.

The lower findings for OMFS and Prosthodontics could be attributed to the incomplete documentation on patient records as they were some challenges in retrieving electronic health records for patients seen in these departments. Also, it could be attributed to the poor consideration for soft tissues that may have influenced the long-term survival rates of the implants (Benghazi et al, 1996; Bouri et al, 2008; Kim et al, 2009). Similarly, the lower survival rates for implant outcomes in Prosthodontics could be associated to limited number of implant placement, as the prosthodontics residents did not place any implants after the 2012. The implant placements were achieved by the prosthodontic graduates enrolled in their fellowship program during 2011-2012. The residents in the prosthodontics department did not have any surgical training during their residency. Moreover, the patients in both OMFS and prosthodontics did not undergo a meticulous periodontal maintenance program as the patients in the Periodontics department are enrolled in their maintenance program following treatment. Literature has emphasized on the importance of maintenance for dental implant survival rate and the interval varies between 3-4 months in the first year of implant placement to 6-12 months afterwards (Lang et al, 1994; Todescan et al, 2012; Wilson et al, 2014). Gay et al (2016) in his long-term retrospective analysis of implant outcome advocated regular

maintenance of dental implants and reported decrease in complications by 90% when compared to those patients who received no care. He also reported reduced failures by 60% in patients who had erratic maintenance schedule.

The study compared the various major implant systems such Zimmer, Straumann, Nobel, Astra, Biomet 3i, Biohorizons, Ankylos and Keystone and assessed their implant survival rate. The purpose of these comparisons was to establish if implant surfaces, length and diameter influenced the success rate of the implant. The study included variety of implant length ranging from 6mm to 16mm implant length and diameter varying from minimum of 3.25mm to 6mm. The implant dimensions did not show any significant associations with implant outcome. Annibali et al (2012) in his systematic review advocated use of short implants (<10mm) in atrophic alveolar ridges. Their cumulative survival rate of 99.1% and over the period of 3.2 ± 1.7 yrs (mean ± SD) they performed well biologically and biomechanically with a success rate of 98.8% and 99.9% respectively. Sung Ah Lee et al (2013) reported similar short-term survival rates for rough short implants (5-8mm) and long implants (>8mm) however the 5 year cumulative survival rates for long implants dropped to 88.5% while shorter implants had the rate of 93.4%. This study attributed lower survival rates for longer implants to complex clinical surgeries, technique sensitive procedures thus contributing to multiple surgeries, increase cost and time. On the contrary, Lemos et al (2016) cautioned use of shorter implants (4-7mm) as they presented with lower success rate and higher risk for failures in the posterior sites. In all, the study derives unremarkable conclusion from its analysis and reports implant length and diameter did not influence the clinical outcome of the implant survival. However, the additive surfaces of the implants provided superior performance and clinical efficacy by improved osseointegration.

The survival rates for Straumann, Zimmer and Astra were found to be high and appears to be in a similar range to the published data. The higher rate can be attributed to surface activation on these implant surfaces that provided increased surface area for osseointegration.

Straumann- SLA and SLActive implants were used for placement in this study. The survival rate of 96.8% was calculated based on the failure of 5 from 155 implants placed. Schwarz et al (2007) reported high bone fill and increased bone height that led to overall improved osseointegration around SLA implants in his histological analysis. Similarly, French et al (2015) reported a cumulative survival rate of 98.4% over 7 years follow up for Straumann bone level and tissue level implants.

Zimmer- The implants included in this study were tapered screw vent (TSV). The survival rate of 96.02% was calculated based on the failure of 15 out of 377 implants placed. In a university hospital study conducted by Nagi et al (2016) 223 TSV implants were placed in maxilla and mandible and were restored as single crowns, bridge or overdenture abutments. The cumulative survival rate calculated for these implants over 6 years was 96.9%. Moreover, the high survival rate was concluded by Minichetti et al (2005) as TSV had a long term superior performance in grafted extraction sockets over 36 months period.

Astra- The implants included in the study were osseospeed. The survival rate of 95.58% was calculated based on the failure of 5 out of 113 implants placed. The higher performance of the implants was attributed to the active surface treated with fluoride thus aiding in osseointegration by promoting osteoblast differentiation (Isa et al, 2006). Moreover, the implant geometric helped in better distribution of axial forces through the implant body towards apical bone rather than creating stresses on the crestal bone (Hansson, 2000).

The study further aimed to identify association between type of clinical training and implant outcomes. Overall, Group 4 performed well followed by Group 3, Group 1 and Group 2. The results are consistent with the literature that reports positive association between increased clinician experience and improved outcomes, based upon their greater emphasis on soft tissue management and their greater experience in placing implants (Brayer et al, 1989; Kocher et al, 1997). Lambert et al (1997) reported clinicians who placed more than 50 implants were 2 times more likely to have a better clinical outcome compared to inexperienced clinicians while the newer literature does not report significant influence of operator experience on dental implant outcomes. Melo et al (2006) in their

university based study reported 91% survival rate of implants placed by OMFS residents that were followed up for over 6 months. Similarly, Kohavi et al (2004) reported an unremarkable association in implant outcomes between novice and experienced operators. The findings conclude that level and type of clinician training will have a remarkable impact on implant failure.

Based on the analysis of the electronic health records, the study findings indicate that the type of clinician training and experience have a positive association with implant outcome. Overall, third year residents performed well achieving improved results following their faculties. The results emphasize on the importance of aggressive clinical training endured over years in residency along with detailed knowledge of the literature that allow development of clinical judgement and skills. These abilities allow them to address complications that may occur during surgeries thus reducing the failure rates. The results also bring forth attention to the concept of "dental implant training over weekend". The dental professionals are subjected to grueling sessions comprised of hands on training in simulation labs or live patients along with plethora of literature compacted into several short presentations. While the concept does provide continuing education to these professionals allowing clinical skill development and treatment planning proficiency, however, one cannot argue on the importance of systematic and meticulous training provided in an academic setting that allows gradual honing and development of expertise of dental professionals. There are several studies indicating increase in implant failure rates in general practice setting (Da Silva et al, 2014). Lastly, the study finding will also allow for potential redesign of the implant curriculum in dental school setting in order to minimize implant failure.

Conclusion:

Amongst the several predictor variables analyzed, discipline, implant systems and clinical training showed significant associations with implant failure. We conclude that the implants placed by the residents in General Practice Residency had the highest success rate followed by Periodontics, Prosthodontics and Oral Maxillofacial

Surgery; however the highest number of successful implants were placed by Periodontics (835) followed by Oral Maxillofacial Surgery (346), Prosthodontics (161), General Practice Residency (36).

It is evident that the level and type of clinician training has an impact on implant failure rates in different residency programs. Further studies may be necessary to identify the reasons for the differences in implant failure rates as well as what potential changes in curriculum could be recommended to minimize these.

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