Analysis of technical complications of prosthodontic restorations made by dentistry students – a ten-year retrospective study

Nora Yosef,

Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Norway.

Hans J. Rønold, DDS, PhD

Department of Prosthetic Dentistry, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Norway.

Abstract:

The aim of this retrospective study was to compare the annual remake rates of single crowns between two Norwegian universities in order to see if there was a significant difference. Our other objective was to quantify the most commonly occurring causes of remakes when it comes to restorations made by dental students at the Faculty of Dentistry in University of Oslo. Lastly, we examined the technicians' perspective on the quality of the work submitted by dentistry students.

1042 standardized remake forms were archived in the university clinic from 2005-2015. In each remake form the type of restoration was selected, followed by the cause for remake, which was then signed by a prosthodontist. The data was analyzed and the frequency percentage for each cause was calculated. 4 different dental laboratories used by the university were given a standardized survey on the quality of the work done by students in addition to the written prescriptions.

The primary cause of restoration failure was inadequate fit, followed by poor marginal adaptation. No significant difference was seen between the University of Oslo (UiO) and University of Bergen (UiB) when it came to annual remake rates of single crowns during the selected 10-year period. The technicians reported a lack of specification when it came to the height of metal margins.

Further research in classifying the most common causes for technical complications that occur to restorations will help identify patterns that could improve future education in prosthodontics.

MESH terms: Dental Technicians, Dental crown design, Dental restoration failure, Dental prosthesis design, Dental Impression technique.

Introduction:

Inconsistencies in the quality of prosthodontic restorations and facing the challenges that accompany restoration failure are relevant clinical problems in today's dentistry. In order to meet the patients' expectations of esthetics and function, effective communication between the dentist and the dental technician is paramount. Improving the quality of dental restorations begins with finding the causes of technical failures.

Prosthodontic constructions are technically demanding, and have to survive in a biological environment in order to succeed. The survival, and to a certain extent, the success of dental restorations are reported as probabilities. Success and survival are terms often used in literature as measurements of the longevity of a restoration. Generally success is defined as the demonstrated ability of a restoration to perform as expected, while survival entails that a restoration required adjustments or repair in order to function. Failure on the other hand is defined as any condition that leads to replacement. This does not necessarily mean that what constitutes a successful treatment by the dentist is considered so by the patient. Restoration failure could be measured in technical and biological parameters. Biologic causes of restoration failure include secondary caries, irreversible pulpitis, necrosis and parafunctions that cause complications (1).

This study focuses on the technical aspects of a restoration failure, which are weaknesses in the restoration itself. These complications can be caused by poor planning, dimensioning of the tooth and the material, choice of material, the impression and each following step in the process that relies on the dentist, technician and their communication. This cooperation depends on their awareness of each other's clinical and technical abilities (2).

Additionally it is important to realize that a thorough treatment plan provides the basis for a successful treatment and a comprehensive assessment of the patient during the initial treatment phase. Unsuccessful clinical results are in most cases related to inadequate communication with the patient(3).

Inadequate communication of design information results in a prosthesis that has been fabricated with little reference to important clinical or biological information. The potential of poorly designed prostheses to cause tissue damage is well recognized(4).

In a study conducted in china where 1600 questionnaires were distributed to five major laboratories, 78% of the dental technicians claimed that the written instructions were inadequately prescribed, but only one-third of them would contact the dentist for clarification (4). Another study conducted in the UK showed that a total of two-thirds of all written prescription failed to meet relevant ethical and legal guidelines, and that a breakdown in communication despite a close working relation is evident (2). It has been shown that there are benefits to be gained by linking the training of the dental

undergraduates to the training of dental technician students, where observational studies indicated a significant benefit from a closer collaboration during training (5, 6).

Our aim is to compare the rate of remakes in UiO and UiB in order to classify differences and similarities between the schools, and factors that could influence them. In addition we wish to identify the most common causes of remakes made by dentistry students in UiO. The null hypothesis is that there is no significant difference between the universities when it comes to the mean rate of prosthodontic remakes.

Restorations of unacceptable quality will in addition to increased expenses, lead to delays and additional work in a fast paced student environment. These remakes can occur as a result of inherent inaccuracies in clinical and laboratory procedures. A quality assessment of prosthodontic constructions can contribute to improving future education in this field as well as reduce the rate of remakes. An important aspect to consider is if there are any existing measures that are effective in reducing these remake rates. According to the American Dental Association's (ADA), QA is defined as "a cycle of quality assurance that involves setting goals, determining outcomes, and collecting data in an ongoing and systematic manner to measure the attainment of goals and outcomes". This is followed by corrective measures to strengthen the program and reduce the incidence of these errors. There have been intervention studies where a Quality Assurance (QA) program has been implemented, with promising results (7, 8).

Materials and methods

Remake forms are a part of the clinical protocol in UiO as a part of a quality assurance program. Students submit remake forms when a prosthodontic construction is of unacceptable quality, or has to be remade as a result of complications. The faculty and administration were informed prior to the implementation of this program. The sample consisted of 1042 forms, from the period of 2005 to 2015. The completed forms get authorized and signed by a specialist in prosthodontics, and a copy is sent to the technician lab with instructions for the new restoration.

The remake forms consist of the following information:

Date of remake, patient name and ID, name of technician lab, an assessment of economical responsibility followed by the type of restoration (Table 1).

(Table 1: Type of prosthesis and cause of remake)

The table shows a list of complications under 5 categories present on the remake form:

Inlay/Onlay	Crown
Metal Ceramic	Gold Crown
Porcelain Crown	Other
Complete denture	Removable partial denture

Problem:	Cause:
1) Fit/adjustment	
Cervical limit	Too short/too long
Fit on prepared tooth/mucosa	Tight/loose
2) Esthetics	
	Wrong color/Visible metal
3) Anatomy	
Proximal contacts	Mesial/Distal
Occlusion/ Articulation	Low/High
Interdental space	Tight/Open
Tooth anatomy	Over contoured/Under contoured/Wrong pontic
Tooth alignment	Wrong
Post-core	Unstable/short/conical
4) Technical	
Cast	Porosity/ Under dimensioned
Fracture	Under trial/ during 6 months
Prosthesis design	Wrong retention elements
Other	

The following is a guide to the remake forms provided by the clinic with possible suggestions to the cause of remake:

Fit/Adjustment:

In this section any marginal discrepancy is registered, based on cervical limit and fit on the tooth and the surrounding mucosa.

The possible laboratory complication could be that the technician misread the marginal line, model defects, too much spacer or an incorrect wax investment.

Possible failures in the clinic could be inadequate impressions, or an imprecise preparation finish.

Esthetics:

Crowns or restorations with unacceptable esthetics were included in this section.

Possible technician lab failure could be a misunderstanding of the prescription, while clinical failures could be caused by wrong color selection or gingival retraction.

Anatomy:

Anatomical failures are related to proximal contacts, occlusion, tooth contouring and placement in removable dentures. Incorrect mountings or wrong assembly according to the bite index could cause technician failures. Clinical causes of such failures include inadequate preparation, imprecise bite registration or a lacking prescription.

Technical failures:

These failures are related to casting, fractures that occur before 6 months of cementation or failures connected to prosthesis design.

Possible causes for these types of failures are based on the type of complication.

Other:

In this section the student or instructor can elaborate on the type of failure, inform the technician and explain complications that are otherwise not listed.

The data was archived in the clinic and was then manually entered into an excel sheet. A review was made in order to minimize human error. The completed Excel sheet was then transferred to the IBM SPSS statistics program and analyzed. The sample was put into a frequency table where the percentages were calculated. A study conducted by the University of Bergen (9) had calculated the mean percentage of remakes of the total crowns produced in 2005-2011. In order to compare the available data the total amount of single crowns produced in this period was calculated by the journal system. An independent t-test was performed in order to evaluate statistical significance.

In the third part of this study we contacted 4 technical labs used by the faculty. The following survey was given to the technicians:

1) What are the most commonly occurring mistakes you see when it comes to work delivered by Oslo University students?

2) How is the quality of the impressions delivered to your lab?

3) How are the bite registrations?

4) Are the primary casts adequate?

5) Do the written prescriptions contain clear and understandable instructions?

Results:

The results were obtained as data output on overall remake percentages from January 2005 through December 2015.
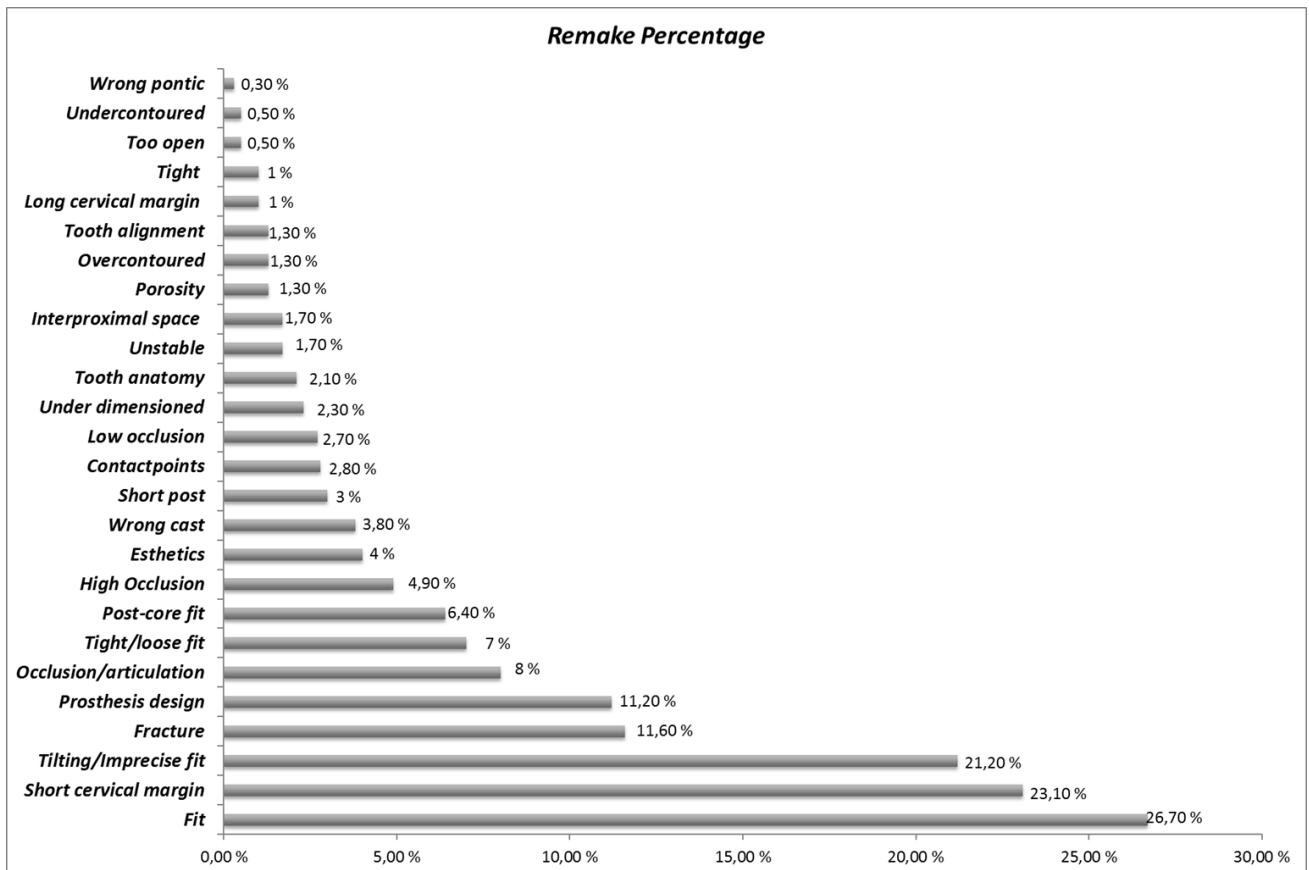

Figure 1: 25,4 % of remakes were reported under "other" causes.

25,4 % of the remakes were caused by other reasons than the ones listed in the forms. These included comments or additional information regarding the remake. Of the remake causes where the responsibility lied in the clinic, inadequate crown retention was reported as well as a poor tooth preparation with undercuts. Porcelain or metal fractures were also commonly occurring problems. Of the biological causes for failure caries and changes in the treatment plan such as extraction were cited in some of the cases. Abutment fracture was reported in 5 of the remake forms. A few cases cited wrong cementation as the primary cause of remake. As far as RDP works, an unclear design in the prescription combined with inadequate fit was the primary cause for remake.

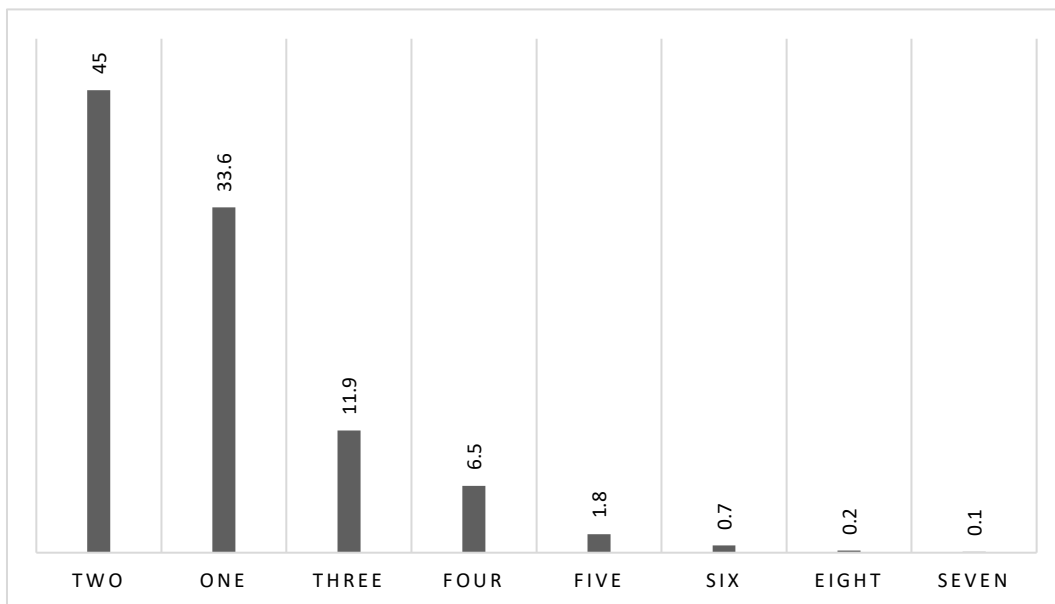The diagram (figure 2) shows the number of causes listed in the remake forms.

Figure 2: Number of causes cited in the remake forms, percentage

An average of 614 crowns were made per year, where an average of 37 had to be remade (figure 3 and 4). The average remake rate from 2005-2015 was *6,1%* in UiO. In Bergen University an average of 440 crowns are made per year where an average of 23 had to be remade during 2005-2011. The mean remake rate was then calculated to be *5,2%*(9). A t-test was performed with a p<0.05 showing *no statistically significant difference between the universities* when it comes to the average remake rate*.*
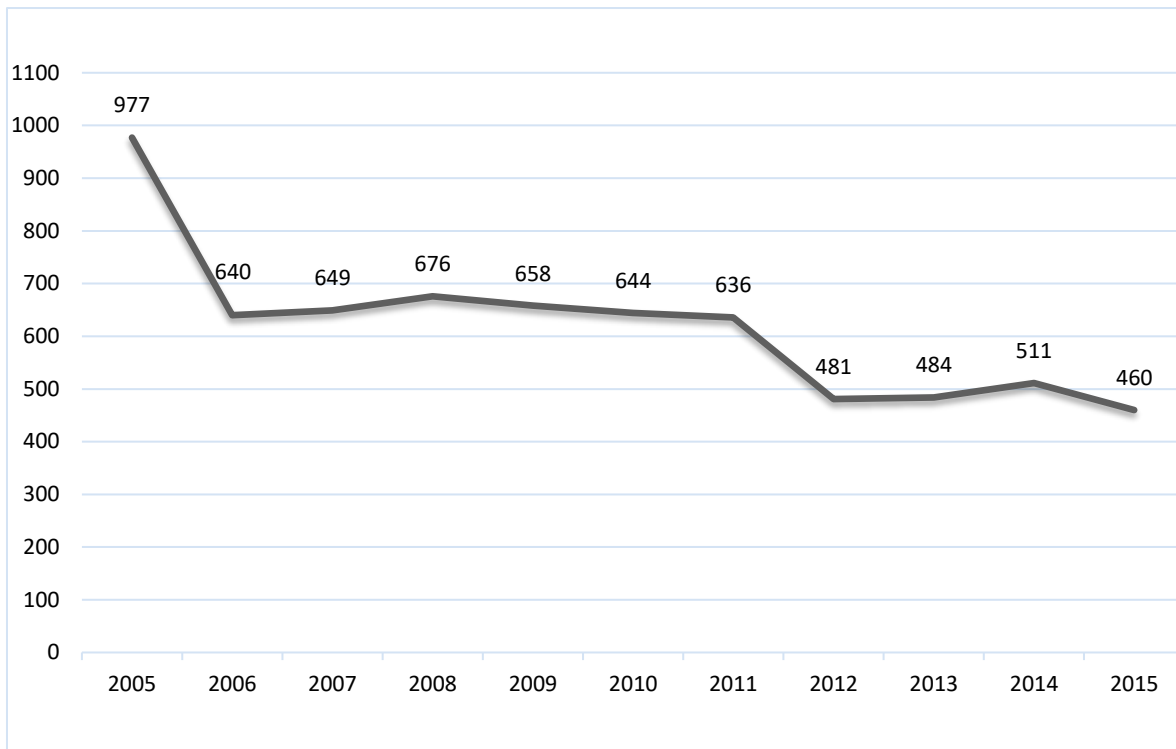
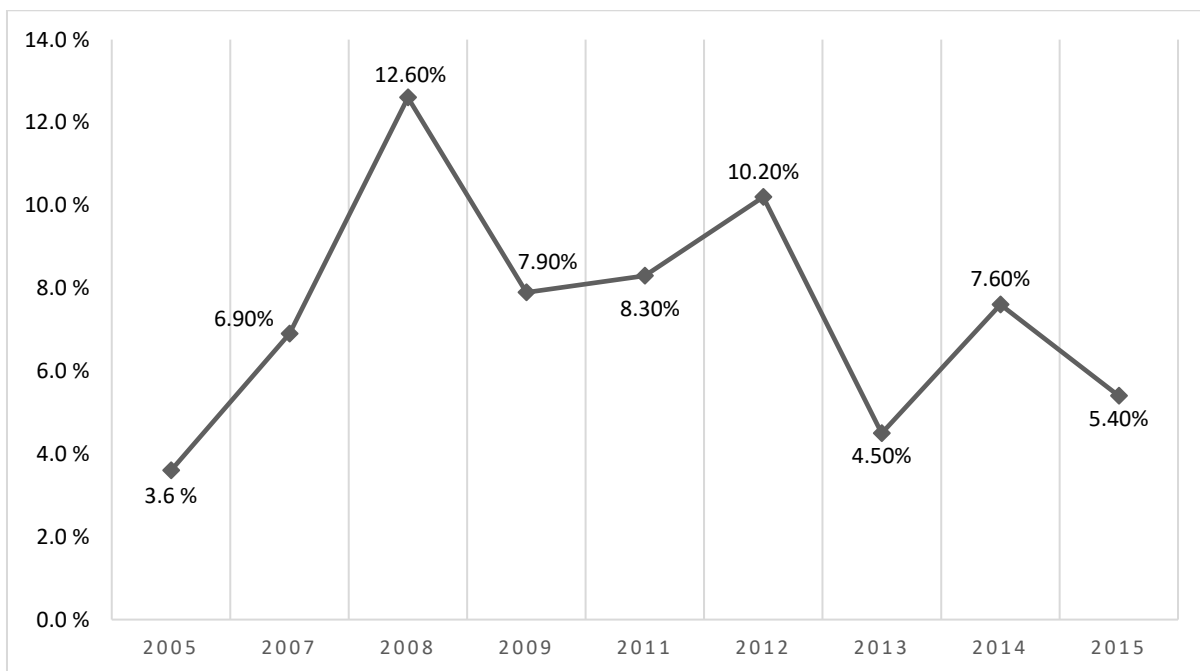*Figure 3: Total number of crowns produced in UiO, 2005-2015*

Figure 4: Remake percentages of single crowns 2005-2015

Our study found that 62,8% of the remakes were connected to the technician lab, while 27,9% were related to the clinic. In the remaining cases the responsibility was unclear.

According to the technician labs the most frequently occurring mistake was the lack of antagonist in post-core constructions. The quality of impressions was reported to be variable. In cases where the preperation margin was unclear the labs would ask for a new impression. A frequently occuring problem with bite registrations for removable partial prosthesis was a lack of contact between opposing jaws in the registration. The primary casts sent by the students were reported to be mostly adequate, and the labs would ask for new ones in cases of complications or damage. The technicians reported a lack of specification on the height of metal margins on the buccal, approximal and lingual surfaces in the prescriptions.

Discussion:

This study set out to categorize the most frequent factors influencing the quality of prosthodontic restorations that occur in the student clinic. Several complications in the general practice occur because the dental undergraduate usually performs a minimal amount of tooth preparations with few time constraints, and will then try to incorporate the same quality in a fast paced practice environment as a dentist. The result is a degeneration of quality of the finished product (10). By categorizing the causes for prosthodontic remakes in the early stages, we can anticipate possible future complications and prevent loss of resources.

In this analysis we chose not to restrict our findings to single crowns, and rather focused on all types of fixed and removable prosthodontic restorations. The consequence of this is a more generalized view of the represented data, serving as a general guide to failures in the technical manufacturing process.

A retrospective analysis of pre-existing data will have its according limitations. One possible cause of recall bias is that none of the remake forms could be traced back to the person filling out the form, making it difficult to analyze in retrospect. Several of the filled out forms lacked all the available data to be conclusive to the cause of remake, and had to be excluded. Another limitation was the amount of missing data where the restoration was adjusted in the clinic without filling out a form, indicating a tendency of underreporting.

The rates of remakes that were compared in the two different universities were based on mean percentages that generalize the findings. Since our study was not limited to single crowns, and the remake forms used in Bergen University are different from the ones in Oslo, the data was not comparable enough to draw comparisons in other ways. Despite these limitations our null hypothesis of no significant difference between the universities' remake rates was verified.

As shown in figure 1, over 26.7% of remakes were caused by inadequate fit, 23.1% of the crowns had short gingival margins and 21.2% had problems with tilting. These findings are consistent with a similar study conducted in University of Illinois, Chicago where unclear margins on impressions was cited as one of the top five most common errors for indirect restoration submissions(11).

It is often cited that the marginal fit of any dental restoration is essential for success (12). Several studies have attempted classifying marginal discrepancy or "fit", with varying measurements and descriptive terminology. Some investigators have reported measurement of fit relative to the marginal adaptation, internal adaptation, vertical seating, radiographic appearance and clinical adaptability judged by experienced practitioners. One defining study conducted by Holmes(13) classified the fit of a restoration based on the degree of "misfit". Marginal fit was then classified based on the presence of a marginal gap. For example an overextended margin was defined as the perpendicular distance from the marginal gap to the casting margin. Similarly an under extended margin was defined as the perpendicular distance from the marginal gap to the surface angle of the tooth.
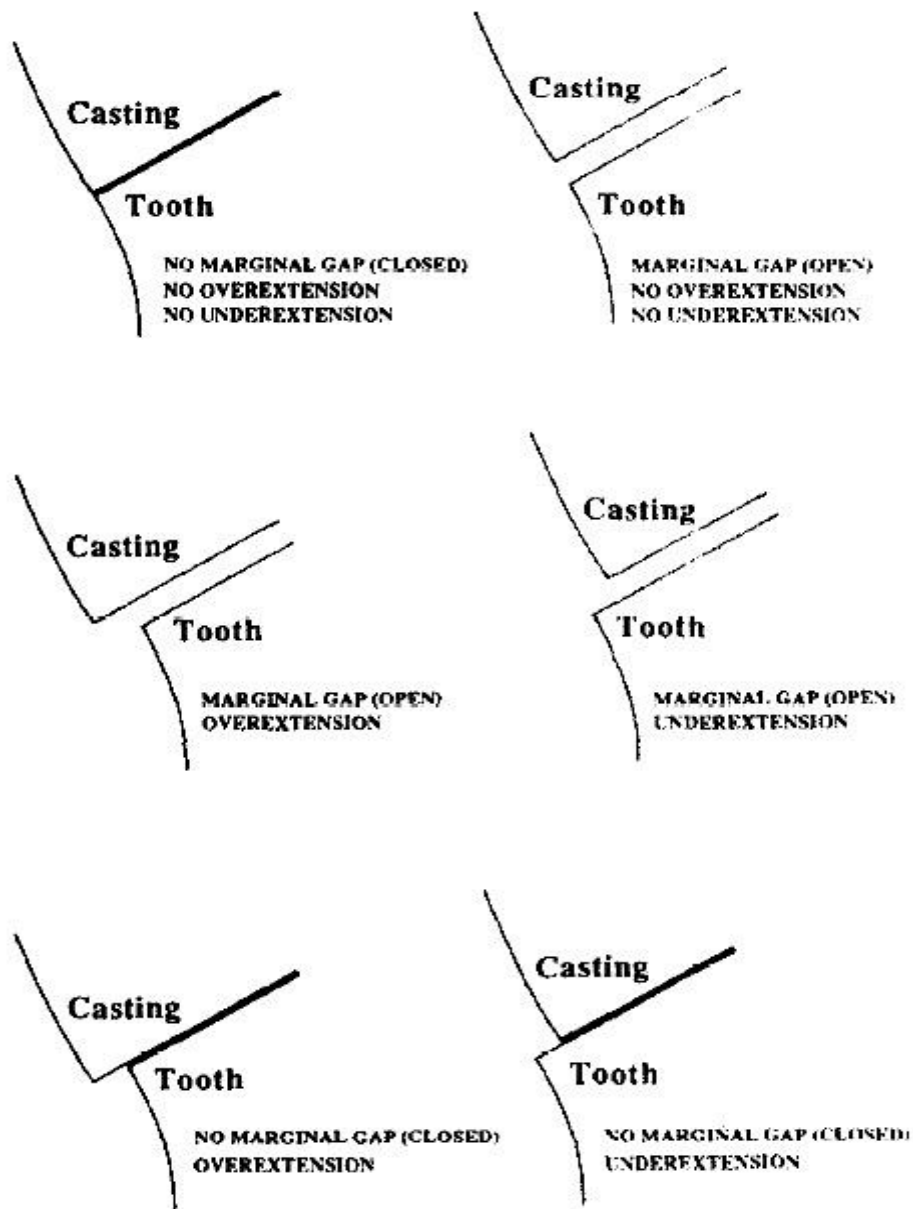
Figure 5: Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit.

It is natural to link these internal precision failures to the impression. Studies indicate that a concerning one third of impressions do not accurately reproduce the finish line (10, 14, 15). Other visible flaws indicated in the literature include: air bubbles in critical places, voids or drags of the impression material and unset impression material on the surface. More invisible impression flaws that resulted in a good fit on the die, but poor fits clinically, were: tray and impression recoil, impression detachment from the tray and permanent deformation. It is also shown that with an increase of preparations in an

impression, the likelihood of such flaws occurring also increases(14). The cause of misfit is thus variable for each case, and should be evaluated individually.

When it comes to the external precision of the new crown to the surrounding teeth and structures, over contouring was cited as a prominent cause of remake, often as an attempt by the technician to reduce the possibility of fracture by increasing the volume of the material. The presence of over contouring in restorations is an iatrogenic factor propitiating gingival inflammation and compromising the esthetic outcome and thus increasing the risk of biological failures. Likewise a poorly fitted denture can propagate the occurrence of infections. These complications can be reduced by considering the anatomic reference and effective communication with the technician (16).

A similar retrospective study by Imbery et. al. found that regarding work authorizations, 43% overall did not provide sufficient information or had technical errors that delayed prosthesis fabrication. The most common errors were incorrect mountings, absence of solid casts, inadequate description of margins for porcelain fused to metal crowns, inaccurate die trimming and margin marking. The primary cause of these recurring failures could be due to a potential lack of understanding of laboratory procedures due to decreasing amount of courses on dental technology during education. This highlights the ongoing need for faculty development and calibration to ensure students receive the highest quality education in fixed prosthodontics (17).

The surveys we sent to the technicians indicated that they would report back if the work was inadequate, but this is contradicted in the literature(4). A more effective design of the survey with a Likert scale could have given more quantifiable information, but the number of technician labs was limited. Despite these limitations the technician lab in our study recorded a lack of specification in the prescriptions when it came to the gingival finish, which is consistent with the available literature. In these studies a large amount of prescriptions were classified as "guides" that left major decision-making up to the technician. Shade selection was also often lacking. Qualified dentists were less thorough in filling out prescriptions compared to dental undergraduates (2, 18).

The fact that 62,8% of the remakes were connected to the technician could be caused by inadequate prescriptions. This could be caused by our lack of awareness of the

impression as a way of communication, combined with the fact that the technicians rarely respond to inadequacy in quality.

A study by Chan et al. identified three common themes among technicians: a lack of recognition by the dental team, lack of communication in the prescriptions and a lack of knowledge by the dentist of technical procedures (11, 19). The poor communication can be a consequence of a decreasing focus on these procedures in curriculums.

An interesting development was observed in our study from the year 2005-2008 (figure 4) with a dramatic increase in remake rates from 3.6% to 12.6%. Accordingly from 2005-2008 the number of single crowns made was reduced from 977 to 676. It is difficult to say if there is a correlation here between the amount of crowns, or practice per se, and the percentage of failures. The remakes could also be a cumulative result of preparations made during the previous years, since the patients could have been transferred to new students. Changes in the education plans and number of faculty members could also have influenced this development.

Over 70% of the filled out forms in our study reported one or two primary reasons for restoration failure, indicating that most technical complication causes could be traced back to a specific part of the preparation and manufacturing process.

When it comes to effective interventions against these complications several studies have shown that QA programs can be effective in measuring and classifying the most commonly occurring discrepancies when it comes to students' laboratory work. Another effective intervention is attending education courses together with the technicians in order to have synchronized and updated knowledge of the available materials and methods of manufacturing(20).

QA programs have shown dramatic improvements in remake rates among students and better calibration among faculty. One study reported a decrease in the remake percentage from 6,29% to 0,55% on QA sites. The percentage of inadequate impressions, the most frequent problem in initial submissions was reduced from 16% to 8% after only 6 months (11). It is important to note that QA programs cost faculty time and commitment during the evaluation process and cause delays in the transport time of the clinical product. This initial investment is outweighed by time and effort saved by avoiding remakes. Quality assurance programs thus help the students evaluate the

quality of their own work and provide consciousness around each step of the process that goes into creating the best possible outcome for the patient (7).

Conclusion:

The objective of this study was to compare the rate of remakes between the two universities. There was no significant difference between the different universities when it comes to the remake rate of single crowns, verifying our null hypothesis. The most common cause of remake was inadequate fit. These findings are important not only from an economical perspective, but also an educational one. By knowing the cause of these remakes we can use this information to further improve educational strategies in this field. This will ensure that the patient gets the best available outcome and establishes the dental technician as an important part of the dental team. Further research could be made on the remake rates and causes when it comes to dentists in actual clinical practice. As shown in the literature there are significant benefits to a quality assurance program when it comes to reducing remake rates and improving the quality of the finished restoration.

1.   Anusavice KJ. Standardizing Failure, Success, and Survival Decisions in Clinical Studies of Ceramic and Metal-Ceramic Fixed Dental Prostheses. Dental Materials. 2012;28(1):102-11.
2.   Stewart CA. An audit of dental prescriptions between clinics and dental laboratories. British dental journal. 2011;211(3):E5.
3.   Rønold HJ SEEJ. Hvordan sikre en god start på en vellykket tannbehandling? Nor Tannlegeforen Tid. 2015;125(162-7).
4.   Lynch CD, Allen PF. Quality of communication between dental practitioners and dental technicians for fixed prosthodontics in Ireland. Journal of oral rehabilitation. 2005;32(12):901-5.
5.   Reeson MG, Walker-Gleaves C, Ellis I. Attitudes towards shared learning of trainee dental technicians and undergraduate dental students. Journal of dental education. 2015;79(1):95-100.
6.   Reeson MG, Jepson NJ. "Bridging the gap." Should the training of dental technicians be linked with that of the dental undergraduate? British dental journal. 2005;198(10):642-5; quiz 8.
7.   Maxson BB, Nimmo A. Quality assurance for the laboratory aspects of prosthodontic treatment. Journal of prosthodontics : official journal of the American College of Prosthodontists. 1997;6(3):204-9.
8.   Metz MJ, Abdel-Azim T, Miller CJ, Lin WS, ZandiNejad A, Oliveira GM, et al. Implementation of a laboratory quality assurance program: the Louisville experience. Journal of dental education. 2014;78(2):195-205.
9.   Øyvind Goksøyr JHG, Olav Egil Bøe, Morten Eirik Berge. Tekniske feilslag ved enkle kroner produsert av studenter ved odontologisk klinikk. Den Norske Tannlegeforenings Tidende. 2013;9.
10.   Christensen GJ. Improving the quality of fixed prosthodontic services. Journal of the American Dental Association (1939). 2000;131(11):1631-2.
11.   Chan CT, Sukotjo C, Gehrke KW, Yuan JC, Campbell SD, Clark DM, et al. Laboratory quality assurance in the Department of Restorative Dentistry at the University of Illinois at Chicago, College of Dentistry. Journal of prosthodontics : official journal of the American College of Prosthodontists. 2013;22(1):85-91.
12.   Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: A systematic review. Journal of Prosthetic Dentistry.110(6):447-54.e10.
13.   Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. The Journal of prosthetic dentistry. 1989;62(4):405-8.
14.   Wassell RW, Barker D, Walls AWG. Crowns and other extra-coronal restorations: Impression materials and technique. British dental journal. 2002;192(12):679-90.
15.   Christensen GJ. The state of fixed prosthodontic impressions: room for improvement. Journal of the American Dental Association (1939). 2005;136(3):343-6.
16.   Vasconcelos FS, Neves AC, Silva-Concilio LR, Cunha LG, Rode Sde M. Influence of anatomic reference on the buccal contour of prosthetic crowns. Brazilian oral research. 2009;23(3):230-5.
17.   Imbery TA, Diaz N, Greenfield K, Janus C, Best AM. Quality of Impressions and Work Authorizations Submitted by Dental Students Supervised by Prosthodontists and General Dentists. Journal of dental education. 2016;80(10):1229-36.
18.   Sui L, Wu X, Wu S, Gao P, Li R. The quality of written instructions for dental prostheses in China. Journal of prosthodontics : official journal of the American College of Prosthodontists. 2014;23(8):602-9.
19.   Juszczyk AS, Clark RK, Radford DR. UK dental laboratory technicians' views on the efficacy and teaching of clinical-laboratory communication. British dental journal. 2009;206(10):E21; discussion 532-3.
20.   Christensen GJ. Improving dentist-technician interaction and communication. Journal of the American Dental Association (1939). 2009;140(4):475-8.