Factors influencing the success of root-amputated and restored maxillary molar teeth

short thesis for the degree of doctor of philosophy (PhD)

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List of the publications providing the basis of and related to the topic of the thesis

<u>Publications providing the basis of the thesis:</u>

I. **Dr. Szabó Balázs**, Dr. Eördegh Gabriella, Dr. Szabó P. Balázs, Dr. Fráter Márk. Gyökéramputált és betéttel restaurált felső moláris fogak törési ellenállásának in vitro vizsgálata - Előzetes tanulmány. FOGORVOSI SZEMLE 110. évf. 4. sz. 2017. 111–116.

II. **Balázs Szabó**, Sufyan Garoushi, Gábor Braunitzer, Balázs Szabó P., Zoltán Baráth & Márk Fráter. Fracture behavior of root-amputated teeth at different amount of periodontal support – a preliminary in vitro study. BMC Oral Health. 2019 nov 27;19(1):261. **(IF= 2.08)**

III. Balázs Szabó P., Tekla Sáry, **Balázs Szabó**.The key elements of conducting load-to-fracture mechanical testing on restoration-tooth units in restorative dentistry Analecta Technica Szegedinensia ISSN 2064-7964 Vol 13 No 2 (2019) DOI: 10.14232/analecta.2019.2.59-64

Introduction

Periodontitis is considered to be one of the most frequently occurring conditions affecting the health of the oral cavity in adults; it is regarded as an important health problem.

In multi-rooted teeth, it can create a unique problem called a furcation involvement, for which treatment is considered to be one of the most demanding challenges of periodontal interventions. It has been previously shown that among periodontally compromised teeth, maxillary molars are the most likely to be lost. One of the reasons behind this phenomenon could be that maxillary molars have a unique root morphology and when attachment loss extends to the furcation, a number of problems arise. By the time the furcation has been exposed, more than 30% of the available attachment surface has been lost. Furthermore, due to the poor accessibility of the exposed furcal area, molar teeth respond less favorably to non-surgical periodontal treatment than single-rooted teeth. Nevertheless, patients prefer to keep their own dentition, and the advances in dentistry make it possible, so teeth that would once be removed are now conservatively treated. It is generally stated that more extensive defects are rather treated surgically. The two main trends of surgical treatment are resective and regenerative periodontal therapy. Resective interventions aim to create a stable, sustainable state based on the current clinical picture by further reduction of the remaining tissues, while regenerative surgical interventions seek to restore the form and function of the original structures. A type of resective surgical intervention is root amputation or root resection.

Root amputation is the surgical procedure by which one or more of the roots of a multirooted tooth are removed at the level of the furcation whilst the crown and remaining roots are left in function .Root amputation can be a valuable procedure when the tooth in question has a high strategic value or when specific problems exist associated with treatment alternatives such as dental implants (e.g.: limited bone due to destruction or due to proximity of the maxillary sinus, periodontally compromised and smoking patients, etc.). The indications for root amputation can be divided into two categories: periodontal and endodontic. Conventional periodontal indications include: moderate to advanced furcation involvement, severe bone loss affecting one or more root(s), severe recession or dehiscence of a root or unfavorable root proximity between adjacent teeth. Endodontic indications could include: root fracture or perforation, external root resorption, failed root canal treatment, root caries or endodontic–periodontal combined lesions. The factors to be considered when deciding which root to remove are as follows: the amount of supporting tissue around the roots, the root and root canal anatomy in relation to the endodontic treatment and the periapical condition. The amount of supportive tissue around the roots, which is of key importance regarding the stability and prognosis of the treated tooth, can vary based on whether the indication is a periodontal one or an endodontic one. Also, it is important to emphasize that as soon as root amputation is indicated, endodontic therapy of the remaining root canals becomes necessary and should be completed prior to the surgical intervention.

In general, the prognosis of endodontically treated teeth depends not only on the success of endodontic therapy, but also on the type of coronal reconstruction. Previously it was recommended that a root-amputated tooth should be restored with a full coverage crown. However, with current adhesive restorations it is possible to restore function and reinforce the tooth without having to sacrifice considerable amounts of healthy tooth structure. Several studies have shown that if a Class I. cavity remains after endodontic treatment, the tooth can safely be restored with a direct composite restoration. However, if one or both marginal ridges are missing after endodontic treatment, restoration with cuspal coverage is highly recommended even in non-root-amputated cases. The question arises, whether the remaining bone level will affect the performance of the restoration-tooth complex in a more minimal invasive (Class I. direct) and a more invasive (Class II. MOD indirect) restorative solution in root-amputated maxillary molar teeth.

Thus, our aim was to in vitro examine the behaviour of root-amputated maxillary molar teeth in situations of static loading. More specifically, to determine how the amount of remaining alveolar bone affects the resistance against static loading, and what role does the dental restoration have in this issue.

Method

pilot study: in the pilot study 40 maxillary molars and 20 maxillary premolars extracted for periodontal or orthodontic reasons were selected for this study. Teeth were used within 6 months after extraction. The first inclusion criteria were visual absence of caries or root cracks, absence of previous endodontic treatment, posts or crown or resorptions. Teeth with severe polymorphism of the coronal structures were excluded from the investigation. Both coronal and radicular dimensions of the teeth were strictly standardized in order to use teeth with the same coronal and root dimensions. Based on these criteria, fourteen maxillary first molars were selected for the pilot study. The rest of the molar and premolar teeth were set aside to be used during the embedding procedure. Teeth were distributed into 2 groups (Group 1 and 2, n=7). Standardized mesio-occluso-distal (MOD) cavities were prepared in both groups. After finalizing the cavities root canal treatment was and root canal filling was performed. After adhesive treatment the missing dentine was rebuilt from short fiber-reinforced composite. Finally, all cusps were reduced by 2 mm of their original height and the cavity margins were refined and prepared for an overlay restoration. The situation was restored with an approximately 2-2.2 mm thick laboratory made composite overlay, which was luted adhesively with pre-heated restorative composite resin. Each mesio-buccal (MB) root was sectioned horizontally at the level of the furcation. Molars and premolars not selected for restoration were used as neighboring teeth to produce a tight interproximal contact on both sides forming a three-teeth unit. Specimens in Group 1 were embedded in methacrylate resin at 2 mm from the CEJ to simulate the normal bone level, while specimens in Group 2 were embedded 3.5-4.5 mm from the CEJ at the level of the furcation to simulate a grade I. furcation involvement. All specimens were quasi-statically loaded with a crosshead speed of 2 mm/min parallel to the long axis of the tooth in a universal testing machine until they fractured. Both fracture resistance and the fracture pattern were evaluated.

Second study: in the second study 180 maxillary molars and 80 maxillary premolars extracted for periodontal or orthodontic reasons were selected. Both coronal and radicular dimensions of the teeth were strictly standardized in order to use teeth with the same coronal and root dimensions. Based on these criteria, sixty maxillary first molars were selected for the second study. The rest of the molar and premolar teeth were set aside to be used during the embedding procedure. Teeth were distributed into 4 groups (Group 3-6, n=15). In Group 3 and 4 standardized MOD cavities were prepared as described earlier. After cavity preparation, the roof of the pulp chamber was removed, and root canal treatment was initiated. Teeth in Groups 5 and 6 received a Class I. cavity preparation which was continued into a traditional endodontic access. Endodontic treatment was performed in all specimen with the same method described in the pilot study and was followed by the sectioning of each mesio-buccal (MB) root horizontally at the level of the furcation. All prepared specimens received the same adhesive treatment and core build-up from short fibre-reinforced composite (SFRC) as in the pilot study. In Groups 5 and 6, the last occlusal layer was composite resin restorative material covering the SFRC, thus they were restored with a direct restoration (Figure 1).

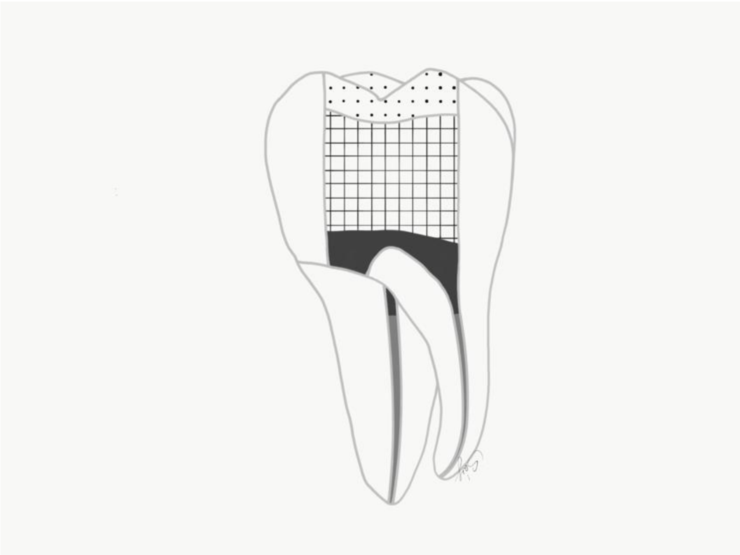

Figure 1. Schematic figure representing the groups (Group 5 and 6) restored with the direct filling.

In Groups 3 and 4, all cusps were reduced by 2 mm of their original height and the cavities were restored with indirect composite overlays (Figure 2) as described in the pilot study. The fabrication of the overlays and the luting of them was the same in both research.

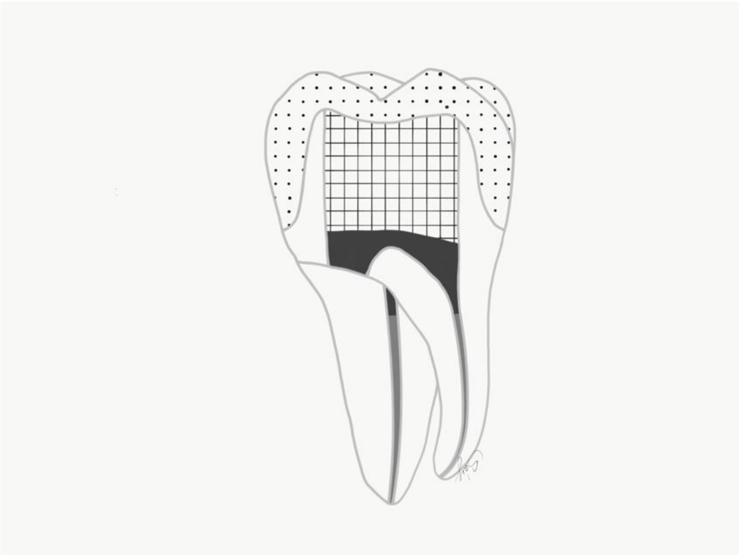

Figure 2. Schematic figure representing the groups (Group 1 and 2 in the pilot study, and Group 3 and 4 in the second study) restored with the indirect overlay.

During the embedding procedures molars and premolars not selected for restoration were used as neighboring teeth to produce a tight interproximal contact on both sides forming a three-teeth unit. Specimens in Group 3 and 5 were embedded in methacrylate resin at 2 mm from the CEJ to simulate the normal bone level (Figure 3), while specimens in Group 4 and 6 were embedded 3.5-4.5 mm from the CEJ at the level of the furcation to simulate a grade I. furcation involvement (Figure 4). Mechanical testing was performed exactly according to the same parameters as in the pilot study.

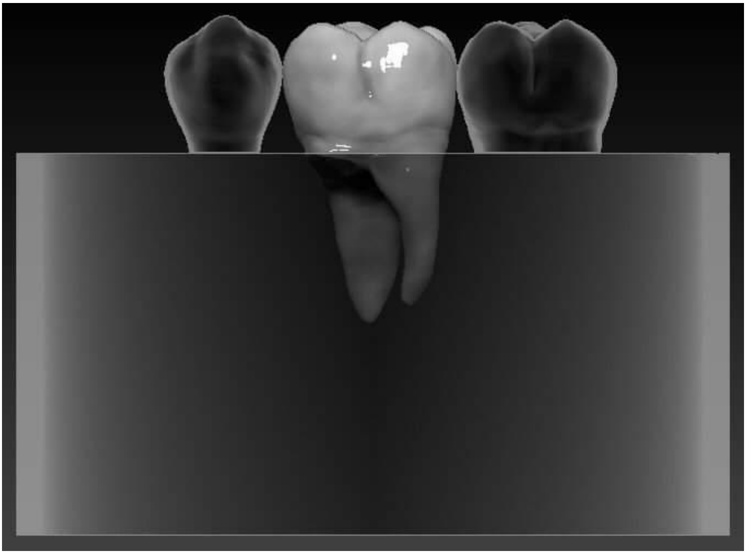

Figure 3. Schematic figure representing the groups (Group 1 in the pilot study, and Group 3 and 5 in the second study) with a simulated normal bone level.

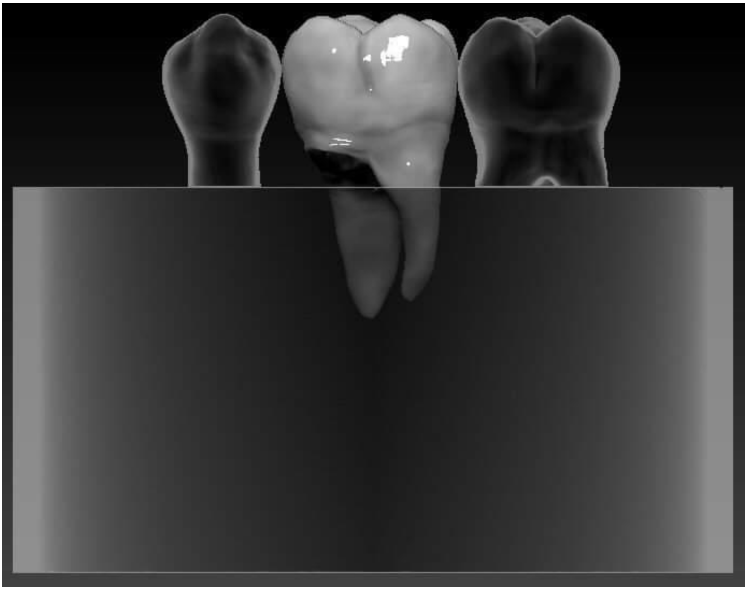

Figure 4. Schematic figure representing the groups (Group 2 in the pilot study, and Group 4 and 6 in the second study) with a simulated Grade I. furcation involvement.

Results

Figure 5. shows the fracture resistance and associated standard deviation for the 2 study groups in the pilot study. In the pilot study the fracture resistance of root amputated teeth with sound periodontal support (Group 1) yielded higher fracture resistance (mean = 2655.53 N, SD = ±1107.27 N, n = 7) than the ones with damaged periodontal support (Group 2) (mean = 1624,12.N, SD = ±535.03N, n = 7). This difference is 1.6 fold, however, due to the small amount of samples statistical analysis could not be carried out.

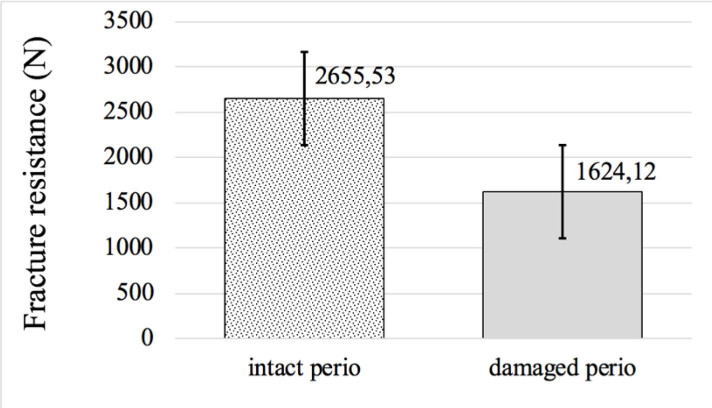

Figure 5. Fracture resistance values and related standard deviation for Group 1 and 2 in the pilot study. The bar chart nicely shows the difference in case of different periodontal support, inspite of the fact that due to small sample size statistical analysis should not be carried out.

Regarding the fracture pattern of the pilot groups all the samples in Group 2 exhibited unfavorable fractures, whereas the ratio of favorable and unfavorable was approximately the same in the group with sound periodontal support (Group 1) (Table 1).

Fracture pattern	**Gr1**	**Gr2**
favorable	4 (57,14%)	0 (0%)
unfavorable	3 (42,85%)	7 (100%)

Table 1. Fracture patterns by group. Numbers of observations and within-group percentages.

Table 2. summarizes the fracture thresholds for the different study groups (Group 3-6) in the second research. Groups without furcation involvement exhibited higher fracture resistance than groups with furcation involvement. Teeth restored with an indirect overlay with normal periodontal support (Group 3) yielded the highest fracture resistance (2311.6 N) among the restored groups and showed statistically significant difference compared to Group 4 ($p=0.038$) and Group 6 ($p=0.0011$). There was no statistically significant difference in terms of fracture resistance between the rest of the groups. The results of the post-hoc pairwise comparisons (Tukey's HSD) are given in Table 3.

Group	**Valid N**	**Mean**	**Minimum**	**Maximum**	**Std.Dev.**
Gr 3	15	2311.60	811.00	3858.00	894.78
Gr 4	15	1682.73	739.00	2502.00	428.64
Gr 5	15	1844.93	1059.00	3517.00	650.22
Gr 6	15	1397.33	686.00	2212.00	395.74

Table 2. Fracture resistance values and related descriptive statistics in the tested groups. Groups: 3- no furcation involvement, indirect overlay; 4- furcation involvement, indirect overlay; 5- no furcation involvement, direct restoration; 6- furcation involvement, direct restoration

Group	Gr3	Gr4	Gr5	Gr6
Gr 3		0.038596	0.184543	0.001153
Gr 4	0.038596		0.892625	0.598182
Gr 5	0.184543	0.892625		0.215362
Gr 6	0.001153	0.598182	0.215362	

Table 3. Significance matrix from the post-hoc pairwise comparisons (Tukey's HSD). The conventions are the same as in Table 2. Significant differences are highlighted in red.

In terms of the fracture patterns (Table 4), Group 5 was characterized by the highest percentage of favorable (i.e. reparable) fractures, while the rest of the groups showed dominantly unfavorable fractures.

Fracture pattern	**Gr3**	**Gr4**	**Gr5**	**Gr6**
favorable	6 (40%)	2 (13%)	9 (60%)	5 (33%)
unfavorable	9 (60%)	13 (87%)	6 (40%)	10(67 %)

Table 4. Fracture patterns by group. Numbers of observations and within-group percentages. The conventions are the same as in Table 1.

Discussion

In both of our studies, different bone levels (no furcation involvement versus furcation involvement) were simulated to investigate their potential effect on fracture resistance of the tooth-restoration complex in root-amputated teeth. In our studies, the simulation of different bone levels seemed to have an impact on the mechanical resistance of root-amputated maxillary teeth. According to our findings in both studies, teeth with sound periodontal support (no furcation involvement; Group 1 in the pilot study, and Groups 3 and 5 in the second study) seemed to show a tendency of higher fracture resistance than teeth with simulated furcation involvement (Group 2 in the pilot study, and Group 4 and 6 in the second study). Moreover, Group 3 showed a statistically significant difference in terms of fracture resistance compared to Group 4 ($p = 0.038$) and 6 ($p = 0.0011$). The reason behind these findings is manifold. Partly, this could be because of the impaired crown-to-root ratio in periodontally compromised cases that leads to inferior results. Also, the type of coronal restoration could have influenced the outcome (see later).

Regarding the possible influence of coronal restorations, in the second study we tested Class I and Class II MOD cavities, as literature considers these the most relevant concerning root-amputated molar teeth. According to previous studies, Class I cavities in root canal treated molars can be safely restored with direct composite restorations. Although root canal-treated teeth are weakened by the access cavity preparation process, the presence of both marginal ridges is still protecting and “splinting” the occlusal tooth structure, leading to a moderate 20% reduction of cuspal stiffness. Meanwhile, a standardized MOD cavity preparation in maxillary premolar teeth was shown to result in an average loss of 63% in relative cuspal stiffness, which is related principally to the loss of marginal ridge integrity. This leads to an approximately 54% reduction in fracture strength. Even the usage of modern fibre-reinforced materials cannot fully reinforce

MOD cavities in root canal treated teeth without cuspal coverage. Extracoronal strengthening by cuspal coverage is generally advisable in case of root canal treated posterior teeth. Traditionally, full coverage crowns have been used, but adhesively placed restorations with total cuspal coverage (overlays) have been proposed lately as a more conservative alternative. In our second study, teeth restored with cuspal coverage restorations (Group 3 and 4) showed slightly higher fracture resistance compared to the groups receiving direct filling (Group 5 and 6) at the same level of simulated periodontal support, though the difference was not statistically significant. The bone level together with an indirect cuspal coverage restoration seemed to have a real impact on fracture resistance of root-amputated molar teeth, since Group 3 was significantly stronger than teeth with impaired periodontal support (Group 4 and 6), irrespective of their coronal restoration. Though increasing the amount of simulated periodontal support seemed to increase fracture resistance, it could not result in a significant difference in fracture resistance when comparing teeth restored with direct filling (Group 5) with the group of simulated furcation involvement (Group 4 and 6). Therefore, within the limitations of this study, it appears that cuspal coverage could lead to better fracture resistance values in root-amputated upper molars, clearly when accompanied with a normal bone support.

In our study, it was only in Group 5 that the fracture pattern was predominantly favorable. We could only hypothesize that this might be due to the combination of conservative direct restoration, the use of SFRC as a core material and a favorable bone level. In the rest of the groups, there was a shift toward unfavorable fractures. The explanation for this might be that all the teeth tested were root-amputated, which not only weakened the structure, but most likely altered the stress distribution pattern as well. Group 5 also contained root-amputated teeth, but in this group, the simulated bone level was favorable, and the coronal structure was more preserved, which could possibly account for an dominantly favorable fracture pattern.

Conclusions

The studies described in the thesis sought to evaluate how the condition of the periodontal support and the type of coronal restoration can influence the fracture resistance and the fracture pattern of root-amputated maxillary molar teeth under in vitro conditions. Within the limitations of this study, both the remaining bone level after root amputation and the type of restoration seems to have significant importance regarding the fracture resistance of root-amputated maxillary molar teeth. It seems that the most favorable combination regarding fracture resistance occurs when root-amputated maxillary molars have healthy, intact periodontium and the tooth has been restored with a cuspal coverage overlay. Although in our study the combination of sound periodontal support and overlay restoration resulted in the highest fracture resistance, this was not accompanied by dominantly favorable fracture pattern. Dominantly favorable fracture pattern could only be seen in case of the combination of sound periodontal support together with the less invasive direct filling. As in many studies and also based upon clinical findings, high fracture resistance and favorable fracture pattern does not necessarily go together. In the authors opinion, contrary to most of the restorative procedures where favorable fracture pattern is the most important thing, as root-amputated teeth are more likely to fail due to sudden masticatory trauma, higher fracture resistance could be a desired feature even on the cost of irreparable fracture pattern in these specific cases.