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Remaining Dentine Thickness Following Tooth Preparation And its Impact on Dentine – Pulp Complex

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Abstract: there are many factors accused of causing pulpal damage, but studies indicate that endodontic complications after placement of fixed prosthetic crowns and bridges are entirely iatrogenic and as a consequence of a deep tooth preparation. In 2mm of the remaining dentine thickness after preparation, there are significant reductions in cellular cell adhesion molecules in the pulp of the prepared tooth data compared to those intact. Researchers confirm that even this decline may be an expression of early stages of pulp inflammation. According to Murray & co, the number of odontoblasts in a dentine thickness of 2.5-0.5mm, was reduced by 13.6%; in a dentine thickness of 0.5-0.01mm, this number was reduced by 33.7%, and in pulp exposure the number of odontoblasts was reduced by 99%. Also, I. Abouta and his associates concluded that the number of odontoblasts and dentine repair activity was mostly affected by tooth preparation (cavity preparation/tooth preparation for crowns) variables rather than the type of filling, material, or patient related factors (age, gender). In a study conducted by A. Vitalariou & Co-authors in order to observe the pulp response in micro in 5 different preparation depth and working conditions groups, the results showed that the displacement of odontoblast nuclei occurs even in a minimum preparation depth of 0.4 mm with optimum working conditions. This study review is to inform the dentists' community with the latest studies and recommendations which raises awareness of the effect that the remaining dentine thickness following tooth preparation, has on the pulp vitality. Studies suggest that clinicists should aim for conservative tooth preparation in order to preserve the vitality of the pulp. The number of odontoblasts and the amount of reparative dentine is disproportional to the amount of dentine removed during the tooth preparation. The remaining dentine thickness in the cavity/tooth has a huge impact on the pulp vitality, and during restoration procedures a dentine thickness of 0.5mm or more than necessary to avoid an irreversible damage of the pulp.

Keywords: the remaining dentin thickness, odontoblast, irreversible pulp damage.

Introduction

There are various factors causing pulp damage and they are already identified and well recognized by clinicians. However different studies continue to conclude that the main factor charged for endodontic complications following fixed prosthetic procedure is the deep preparation. This hypothesis has been discussed widely in dental scientific community since the increasing of endodontic complications was observed right after the beginning of deep preparations for full metal/metal ceramics crowns application. The above was also proven by various studies, on the impact of preparation at different depth and remaining dentine thickness on the tooth pulp.

According to long-term studies, tooth pulp vitality following the tooth preparation has been already identified as a crucial issue related to dentine thickness following tooth preparation, while increment of endodontic treatments following tooth preparation is being noticed more often. [18]

Clinical and histological evaluations, revealed that even though the pulp has good regenerative abilities and inflammatory response which often lead to healing; if the pulp is subject to physiological modifications whether transitive or not, these modifications may be significant in the long term regarding its vitality. [6]

For this reason while deciding on a proper treatment plan, the physician should never take for granted an asymptomatic tooth as it doesn't always has a healthy pulp. The scars remaining after the inflammatory and repair process, alternate and lower the ability of the pulp to resist and response to subsequent damage. [3]

Discussion

Regarding the fixed prosthetic treatment, it often happens that the doctor focuses on technical issues and completely forgets the local and general situation of the patient.

Selecting the appropriate type of crown, should always be in the patients' best interest and should consider functional requirements, the stability and vitality of the tooth structure, as well as the aesthetic requirements or the individual morphological characteristics of each tooth in particular. Metal crowns have the advantage of the minimum required preparation (0.4 mm), while ceramic crowns, composites, or combinations of these materials with metal, require a deeper preparation (1.5-2mm) which means an increased potential to harming tooth structures or functions (in the long run). [8]

Experimentally, it is evidenced that the minimal deviations from these dentine thickness standards have a significant impact on the pulp and its response to preparation. Despite the fact some authors recommend that "the remaining dentine thickness of 0.25-0.50 mm is sufficient to maintain the pulp vitality", these studies also point out that the remaining dentine thickness and conditions under which the dentine preparation is performed, are decisive factors to maintain the pulp vitality.

In 2mm remaining dentine thickness following the preparation, there are significant increasing of the cell adhesion molecules in the pulp of the prepared tooth compared to the pulp of unprepared teeth.

These molecules, which are found in leukocytes and in the blood vessels endothelium, facilitate the main stage of inflammation, leukocyte-endothelial interaction, and the migration of inflammation cells to the local inflammation area.

Initially, a slowdown and a leukocyte rupture occurs on the endothelial surface of the blood vessels lumen side. This slippage and slowdown is assisted by all of the selectines (E, P, L).

Once accumulated leukocytes form a steady bond with endothelial cells, chemio-tactic factors help the dissociation of leukocytes-selectines, and following that a leucocyte-integrin bond is established.

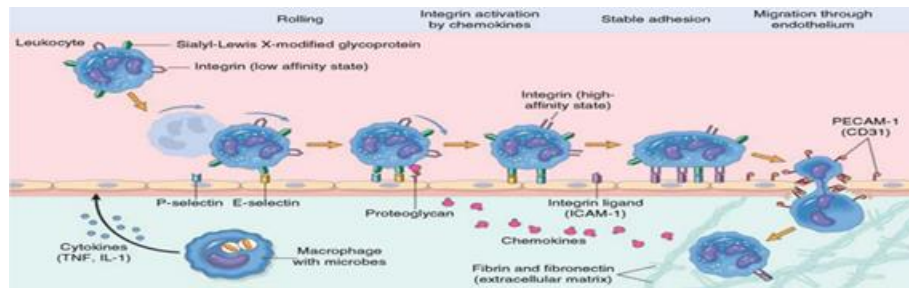


Figure 1. Vessel inflammatory mechanism

Integrines co-operate with the immunoglobulins; respectively with intercellular adhesion molecules (ICAM-1, -2, -3), Vascular Cell Adhesion Molecule (VCAM-1) and Platelet – Endothelial Cell Adhesion Molecules (PECAM-1). This way leukocytes migrate easily in the surrounding tissues (Fig. 1). [1, 4, 7]

Because the characteristics of inflammatory mechanisms are so complex, the researchers suggest that further studies on cellular cell adhesion molecules are needed, in order to clarify the results of this experiment. In conclusion tooth preparation was emphasizes as an affecting factor to the inflammation mechanism even in 2mm remaining dentine thickness. It should be borne in mind that this is the maximum recommended thickness of the dentine remaining during preparation for fixed prosthetic work with the purpose of maintaining pulp vitality. The recommended remaining dentine of the dentine remaining during preparation for fixed prosthetic work in order to preserve the pulp vitality. [5, 17].

The remaining dentine thickness recommended by other authors is even lower. According to Murray and co-authors in a study regarding the number of odontoblasts, their number in a remaining dentine thickness of 2.5-0.5mm was reduced by 13.6%, in a remaining dentine thickness of 0.5-0.01mm the number of odontoblasts was reduced by 33.7%, and in pulp exposure their number was reduced by 99%. Reparative and secondary dentin were found in an average remaining dentine thickness of 0.77mm (2.5-0.001mm). [15]

They concluded that the residual dentine thickness in the cavity had a strong influence on the vitality of the tooth pulp following restoration procedures. A remaining dentine thickness of 0.5mm or more is necessary to avoid irreversible damage of the tooth pulp.

A similar conclusion attained I. Abouta with co-authors. The purpose of the study was to examine the effects of the cavity preparation and restorative treatments on the number of odontoblasts. The variables of cavity restoration in the study was the remaining dentine thickness, the depth of preparation, the general surface, the preparation surface of side walls, the type of restorative material, the volume of prepared cavity, the surface of the cavity floor. It turned out that the number of odontoblasts and dentine repair activity was mostly affected by variables related to cavity restoration rather than the type of restorative material or the patient-related factors (eg. age, gender). [21]

The displacement of odontoblast nuclei following tooth preparation is a phenomenon that is always taken into account, as the high-speed handpiece used for the preparation procedure is already known for as a harmful actor since in the late 1950s. [9,22]

This phenomenon was initially described as "aspiration" of odontoblastic nuclei into dental tubules, but later this term was replaced with the term "displacement of odontoblasts", as this avoids the misinterpretation of any specific mechanism about this phenomenon. [6.18]

By grinding the dentine with the high-speed handpiece during the tooth preparation, it was observed that the pulp immediately reacted with a vascular response.

Immediate pulp response to high-speed burs is described in three stages:

1- Structural changes - the most important stage, it starts with the ending of the normal physiological functions of the dentinal tissue microstructures. This becomes apparent when the odontoblast nuclei are initially oriented towards and then enter through the dental tubular spaces;

2- Vascular response- expressed with dilated arterial diameters, drop of the blood flow in affected area, sometimes accompanied regional abundant bleeding, interstitial edema and circulatory stasis.

3- Accumulation of toxic products from metabolic processes and initiation of inflammatory response in the affected area despite of bacterial contamination absence. Inflammation develops in aseptic conditions as it is induced by endogenous trauma as the result of iatrogenic actions.

The dismantling of odontoblastic nuclei and tubular content has been observed by different studies reported by authors found in international literature. [22, 9, 6, 18]

The displacement of these elements can occur as a result of certain mechanisms as follows:

a- Dental overheating during the tooth preparation due to bur friction, speed and prolonged contact with dentine tissue,

b- Evaporation and disappearance of fluid within the dentin tubules which are on the surface currently being prepared,

c) Exercising burs' high pressure on the dentine tissue, causes aggressive detachment and tubular damage (instead of a delicate and pure classical cut as it is assumed to occur in theory, thus the condition of the tubular cuted margos is neglected, and following this it is also neglected the harming impact it has on natural physiological parameters)

d- Excessive and aggressive dentine air drying, affecting directly the physicochemical balance of dental tissue.

e- In these cases, when tooth preparation should be considered as an aggressive intervention on the vital tooth, the effect of local anesthesia on the neurovascular pulp branch should also be taken in consideration. Local anesthesia supports to a certain extend all the above mentioned elements, reducing this way the pulp ability to react naturally and efficiently to the iatrogenic irritation.

The connective tissue density and pulp fibrosis occurs over the age, but in the case of prepared teeth these changes occur due to the pulp damage resulting from the aggressive influence of the above-mentioned external factors. On the other hand, the increasing pressure in the pulp as the result of the exudate accumulation and interstitial edema may cause the self-destroying of pulp microstructures and thus beginning of a vicious cycle leading to the inflammatory phenomena amplifications. Also, with the increasing pressure inside the pulp, compression of vascular branch occurs, followed by blood flow dropping, interstitial edema and circulatory stasis. This will lead to accumulation of toxic subproducts from metabolic processes. [2, 22, 9, 6, 18]

Pulp changes and the inflammation level happening during and after preparation, corresponds to the tooth depth preparation, and are in disproportionate relation with each other.

The pulp response has already been proven at all levels of tooth preparation techniques by different studies. The pulp reacts due too many factors, the remaining dentine thickness following preparation, the friction heat by high-speed and vibrations of heandpiece used during the crown preparation process, dentine' cold air excessive drying, the effect of local anesthesia on the neurovascular pulp branch, the effect of astringent and hemostatic substances used for the temporary widening of the gingival sulcus during the procedure, even the impression materials or cements have a direct effect on the pulp. [10,11,12]

In a study conducted by A. Vitalariou & Co-authors in order to observe the pulp response in micro; the tooth extraction was performed immediately after the preparation, then teeth were placed in a formaldehyde solution 15%. Based on the type of preparation performed, the sample was divided into 4 groups;

1- The control group with untreated tooth. In this group the pulp functional characteristics were normal.

2- Second group with 0.4mm depth of tooth preparation with water cooling. The pulp changes were invisible, and morphologically it functioned normally similar to the first group (Fig 2).



Figure 2. Odontoblastic nuclei with modified axis and tendency of displacement towards dentinal tubules (HE, ×400)

3- The third group, 0.4mm preparation depth performed without cooling water. Significant changes in odontoblast and vascular area were observed (Fig 3-4).

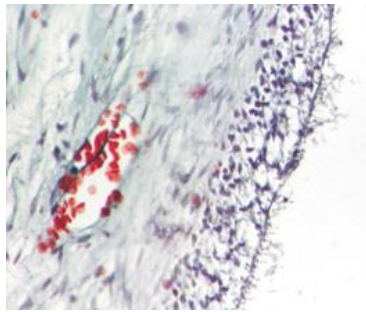


Figure 3. Presenting vacuolation and a slight vasodilatation of the arterioles (Szekelly, ×200)

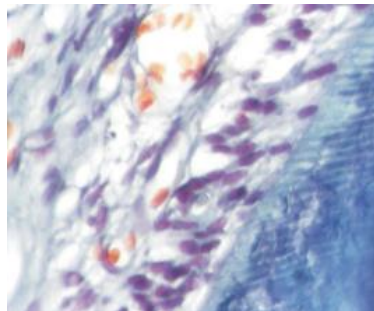


Figure 4. Interrupted and vacuolated odontoblastic layer, odontoblastic nuclei dislocated into the dentinal tubules (Szekelly, ×400)

4- Fourth group, 1.5mm preparation depth performed with water cooling. The remaining dentine thickness was reduced significantly, and despite the fact that the procedure was performed with cooling water, micro changes were even more severe than in the third group (Fig 5-6).



Figure 5. Dentin with odontoblastic nucleus in the dentinal tubule (Szekelly, ×400)

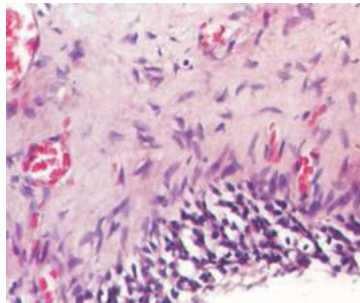


Figure 6. Fibroblasts and fibrocytes agglomeration under the odontoblastic layer (HE, ×200)

5- Fifth Group, 1.5mm preparation depth was performed without cooling water. In this group it was observed that changes were too aggressive and the pulp very badly damaged (Fig 7).

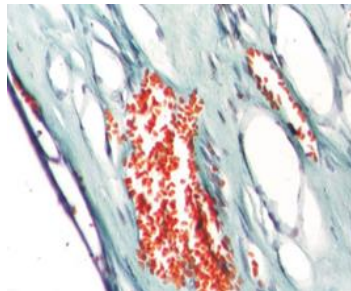


Figure 7. Central pulp: pronounced dilatations in arterio-venous territory (Szekelly, ×200)

Despite the mechanisms involved in the different study groups, the results showed that the displacement of odontoblast nuclei occurs also in a minimum preparation depth of 0.4 mm with optimum working conditions, water cooling etc. The aggressiveness of the changes occurring in the pulp during preparation, depends mostly on the remaining dentine thickness following preparation. This means that even with water cooling or not, during the preparation procedure the remaining dentine thickness is of a great importance. [23]

Relating to remaining dentine thickness following preparation the world literature, it gives some options. However, it is generally recommended that the remaining dentine thickness to be at least

2mm, and this seems to be a key factor in defining the pulp response and to guarantee the pulp vitality, and of course applying at the same time all prophylactic procedures during the procedure (water cooling, quality burs, avoid applying pressure on the dentin, working interruptions during preparation procedure, avoid dentine air overdrying). [13, 9, 14, 15, 16]

Very interesting is the fact that from all the factors involved in the study, the most influential factor remains the remaining dentine thickness, followed by other effecting factors of the number of odontoblasts, factors that have to do with the preparation close to the pulp such as the depth of preparation, the surface of the cavity lateral walls and the basal surface of the cavity.

It has also been noted that the mechanisms developed to prevent pulp damage during tooth preparation planning are entirely theoretical and never directly related to the actual condition of the patient age, gender etc. Thus, among the only mechanisms implemented to date in the literature is "Formula KUZUMI", which has proven the relationship between the age and gender, and tooth dentine thickness at enamel-cement level. These variables can be measured and formula can be applied in the clinic; in order to achieve adequate decortication and to maintain the proper dentine thickness and consequently the vitality of the tooth. This formula has been proven to be successful for teeth 11 / 21-31 / 41, 12 / 22-32 / 42, 13 / 23-33 / 43, 18 / 28-38 / 48, and it is in experimental steps for 14 / 24-34 / 44, 15 / 25-35 / 45, 16 / 26-36 / 36, 17 / 27-37 / 47. [24]

Conclusions

Based on the above-mentioned studies, we can conclude that the disruption of the natural physiological balance of the tooth is in a disproportionate proportion to its vitality and survival, which means that the more aggressive the damage to the natural tooth structure, whether they be reparative iatrogenic interventions (tooth preparation for prosthetic or other restorative procedures), the smaller the chances for the tooth to maintain its biological survival parameters. This encourages us to recommend the most conservative treatment plan for tooth tissues in order to maintain its vitality and provide a second chance to it, so it can be fully functional in the masticatory system.

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