Morphological changes in dental pulp after the teeth preparation procedure

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Abstract

The aim of this study was to evaluate the immediate changes in the pulp-dentin complex that result from crown preparation, and their correlation with the thickness of remaining dentin and the preparation technique (with or without water spray cooling). Thirty upper intact premolars scheduled for extraction for orthodontic reasons were high speed prepared, extracted immediately after preparation and divided in 5 groups. The analysis of the pulp morphology demonstrated that there are several differences according with the preparation technique. The most severe changes appear after the profound preparation without water-cooling, the odontoblastic layer being extremely affected. Also, vascular reactions and inflammatory infiltrate (in the absence of bacteria) were present. Our study revealed that the histologic changes in the pulp and dentin following complete crown preparation occur anyway and they are considered difficult to avoid, even if an adequate technique of preparation is used.

Keywords: dental pulp, odontoblast, histologic changes, full crown preparation.

Introduction

The dentin and the dental pulp are considered as a biologic entity named dentin-pulp complex, with very tight-related elements, a common mesenchymal origin, a conjugated evolution, as well as permanent interactions. For all these reasons, some authors refer the dentin-pulp complex as a histo-physiologic entity [1, 2].

Pulp reactions to the tooth preparation techniques are still a major concern in restorative dentistry [3, 4].

The term "stressed pulp" used in the literature means a bad prognosis from the beginning, because, previous to the prosthesis, caries, old restorations, occlusal trauma, abrasion or periodontal disease already exhausted the pulp adaptability. For such a tooth, any additional trauma, even a small one, can cause a degenerative process in the pulp [5].

According to many longitudinal investigations, there is a high rate of vital teeth exhibiting typical signs of pulp complications, while there is a significantly increased frequency of endodontic treatments following dental preparation and crowns cementation [6-8].

Displacement of odontoblastic nuclei following the teeth preparation is a phenomenon taken into account when high-speed dental engines were introduced in the late 1950s [9, 10].

The phenomenon was described initially as "aspiration" of the odontoblastic nuclei into the dentinal tubules [9, 10], but the term "displacement of odontoblasts" [3, 11] has come into common use because it does not suggest any certain mechanism for its occurrence.

It was demonstrated that the pulp reactivity includes also **immediate vascular responses**, resulted from the grinding of dentin [12-14].

The reactivity of the dental pulp is reported in almost all stages of the prosthetic treatment [15-20], the pulp response being influenced by many factors: the thickness of remaining dentin, the frictional heat and vibrations generated by high speed burs during crown preparation, the excessive drying of dentine, the effects of local anesthesia and of the astringent and hemostatic substances used for the temporary enlargement of the gingival sulcus, the impression and cementation materials.

The first step, the ablation of the dental hard tissues, is a non-biological process by its own destructive nature. Thus, in order to restrict the destructive effect, a minimal removal of dental substance is performed, with the aim to preserve the pulp vitality. There is few data in the literature about the long-term effects of the preparation alone.

These are difficult to assess because the prepared teeth will receive a permanent restoration. Thus, it is considered [3, 21] that the *histological evaluation of the **immediate** structural changes* in the pulp-dentin complex resulting from crown preparation involves two conditions.

The first condition is *to extract the tooth immediately after the preparation*, because no restorative material is 100% biologically inert and thus it is possible to produce a certain pulp response.

The second condition is *to use intact teeth* from young individuals, preferably newly eruptive teeth, the normal structure being well-known and any deviation in structure can be attributed to the preparation procedure.

Unfortunately, the teeth that are to receive prosthetic therapy have or have had caries, posttraumatic fractures, abrasions or old restorations, and in all these instances, the damages to the pulp are already produced.

The aim of this experimental study was to evaluate the immediate changes in the pulp-dentin complex that result from crown preparation, and their correlation with the thickness of remaining dentin (the depth of the preparation) and the preparation technique used (with or without water spray cooling).

Material and methods

For this experiment we used 30 intact upper premolars, newly erupted, scheduled for extraction for orthodontic reasons, from children (10-16 years old). After anesthesia (Scandonest 3%, without vasoconstrictor), the teeth were high speed prepared in two different ways: half of them were superficially prepared (0.4 mm depth) and the other half was profoundly prepared (1.5 mm depth). Every type of preparation was made with and without water spray cooling.

The teeth were extracted immediately after preparation and placed in formalin (15% solution). Based on the type of preparation procedure used, they were classified in 5 groups:

▪ gr. 1 – control (sound teeth, without preparation);

▪ gr. 2 – superficial preparation (0.4 mm) with water sprays cooling;

▪ gr. 3 – superficial preparation (0.4 mm) without water sprays cooling;

▪ gr. 4 – profound preparation (1.5 mm) with water sprays cooling;

▪ gr. 5 – profound preparation (1.5 mm) without water sprays cooling.

The extraction of the dental pulp was performed by the guided fracture of the teeth, aiming for a minimal dilaceration of the pulp. The biopsy fragments were fixed in formalin and routinely processed. The specimens were stained with Haematoxylin-Eosin (HE) and trichrome Szekelly.

Results and discussions

1. Synoptic presentation of the morphologic features

a) Group 1 (control - sound teeth, without preparation)

The microscopic aspect of the pulp from the control group was characteristic for the normal status.

The peripheral pulp presented the three typical areas: the odontoblastic zone, the cell-free zone (Weil) and the cell-rich zone (with Hohl cells).

The odontoblastic layer appeared continuous, uninterrupted, with the cells placed "in palisades". The cells were columnar at the pulp horns, becoming later cuboidal and squamous.

The central pulp revealed a loose connective tissue, with fibroblasts and fibrocytes. As the dental pulp was young, the collagen fibers were few and isolated, dispersed among the cells of the pulp.

b) Group 2 (superficial preparation with water spray cooling)

For the superficially prepared teeth (0.4 mm), with water spray cooling, there were no obvious modifications at the pulp level, the morphological aspects resembling the normal pulp from group 1.

Although, generally, the pulp histology was normal, there should be noted some changes in the position and orientation of the odontoblastic nuclei axis, suggesting a tendency of displacement towards the dentinal tubules (Figure 1), as a result of the high speed preparation of teeth.

c) Group 3 (superficial preparation without water spray cooling)

The superficial preparation (0.4 mm) without water-cooling determined important changes on the odontoblastic zone and in the vascular field.

Thus, there were observed some disruptions and vacuolations of the odontoblastic layer (Figure 2) as well as the irregular placement of the cells, without the normal aspect of "palisades". Also, the movement of the odontoblastic nuclei towards the dentinal tubules was more evident than in the second group (Figure 3).

At the same time, there appeared reactions in the vascular field, comprising vasodilatations and small hemorrhages in the arteriolar and capillary segment.

d) Group 4 (profound preparation with water spray cooling)

In the fourth group, the deeper tooth preparation (1.5 mm) produced an important ablation of the hard tissues of the teeth and a significant decrease in the thickness of remaining dentine. Here, even though the preparation was performed with adequate water cooling, the changes occurred in the dentin-pulp complex were more important than in the case of the superficial preparation. In the peripheral pulp the clear distinction between the three zones (odontoblastic layer, the cell-free zone and the cell-rich zone) disappeared. The odontoblastic layer was interrupted and vacuolated on large areas, with the cells in an obvious disorder. The cell nuclei were displaced beyond the predentin layer, deeper within the dentinal tubules (Figures 4 and 5).

Under the odontoblastic layer we noticed a clustering of fibroblasts and fibrocytes (Figure 6), which are not usually present at this level (cell-free zone). Although the loose connective tissue maintained its normal aspect, this agglomeration of fibroblasts and fibrocytes anticipates the stage of fibrosis in that specific pulp territory.

We also observed in the central pulp the existence of some areas with an abundance of fibrocytes and collagen bundles, together with vasodilatations and important hemorrhages of the large pulp vessels (arterioles and venules). The small vessels were also vasodilated and showed plumped endothelial cells. Other notable features were some microhemorrhages and pulp interstitial edema.

e) Group 5 (profound preparation without water spray cooling)

The histologic sections from the teeth in the fifth group showed that the modifications in the pulp from these cases are extremely severe. Important changes appeared in the peripheral pulp, the odontoblastic layer being completely destroyed. The brutal thermal aggression, caused by the profound preparation without water-cooling, produced at the vascular level a rapid vasodilatation with important hemorrhages (Figures 7 and 8) and exudate, determining an interstitial edema on large areas of the coronal pulp.

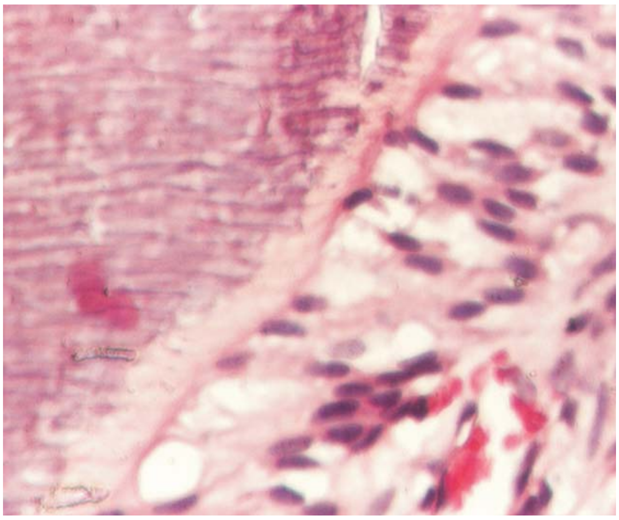

Figure 1 – ***Odontoblastic nuclei with modificated axis and tendency of displacement towards dentinal tubules (HE, ×400)***

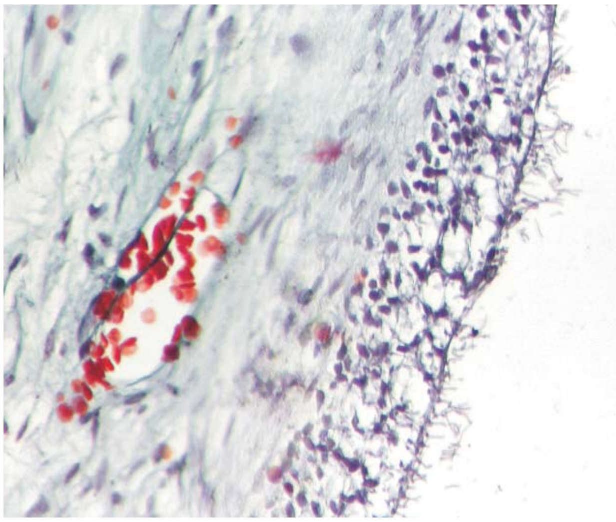

Figure 2 – ***Disrupted odontoblastic layer presenting vacuolation and a slight vasodilatation of the arterioles (Szekelly, ×200)***

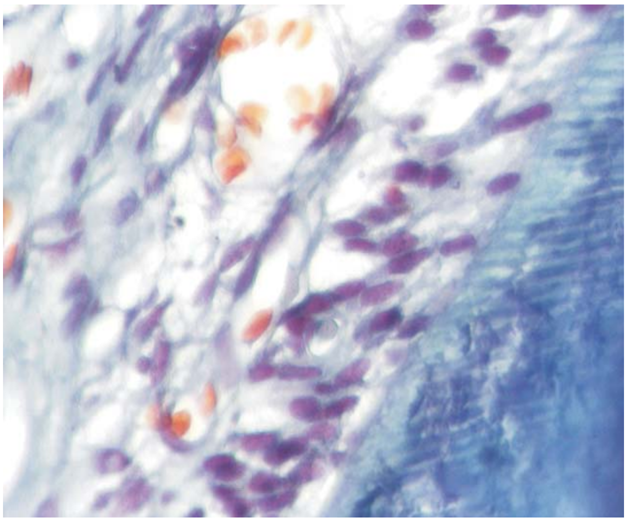

Figure 3 – ***Odontoblastic nuclei displaced towards dentinal tubules (Szekelly, ×400)***

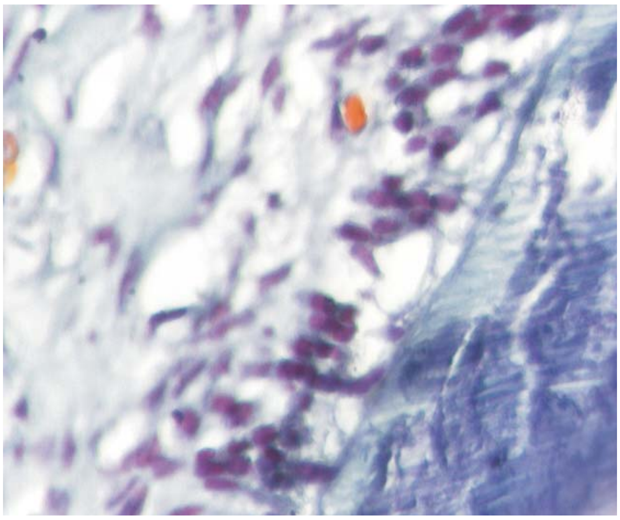

Figure 4 – ***Interrupted and vacuolated odontoblastic layer, odontoblastic nuclei dislocated into the dentinal tubules (Szekelly, ×400)***

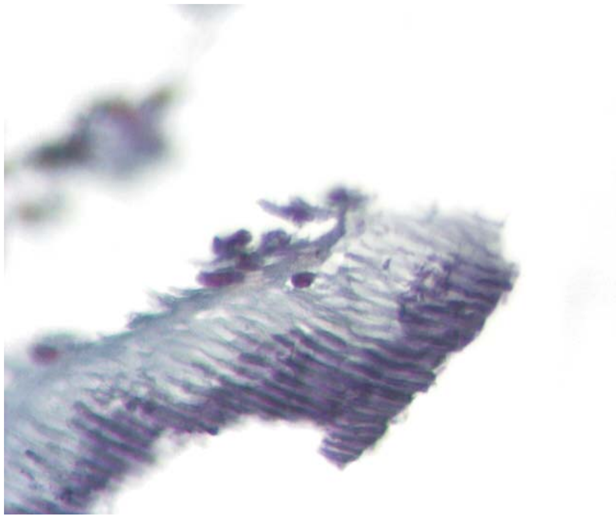

Figure 5 – ***Dentin with odontoblastic nucleus in the dentinal tubule (Szekelly, ×400)***

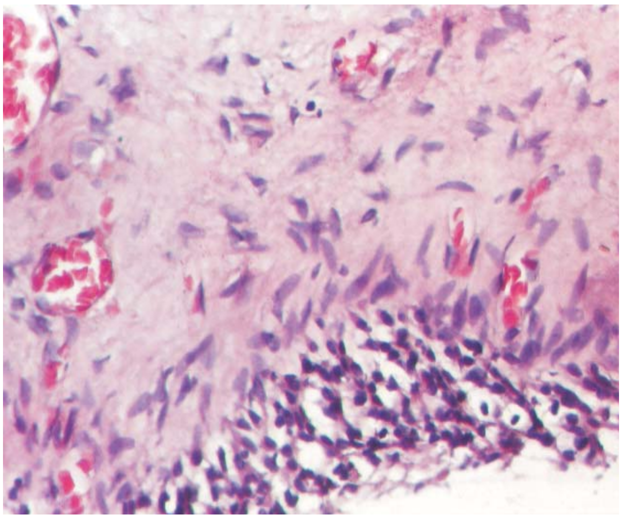

Figure 6 – ***Fibroblasts and fibrocytes agglomeration under the odontoblastic layer (HE, ×200)***

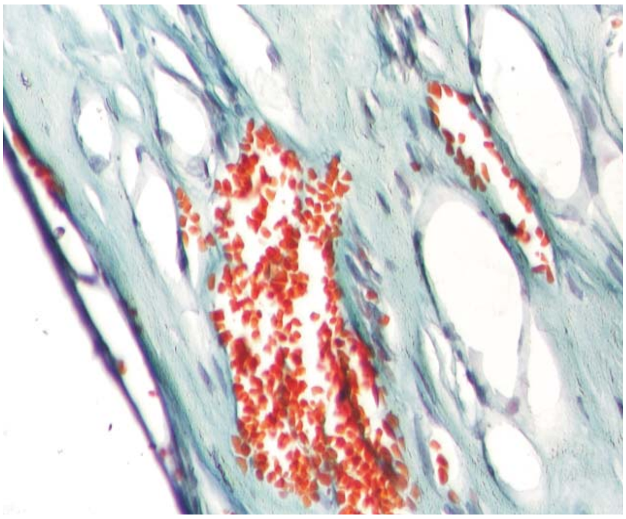

Figure 7 – ***Central pulp: pronounced dilatations in arterio-venous territory (Szekelly, ×200)***

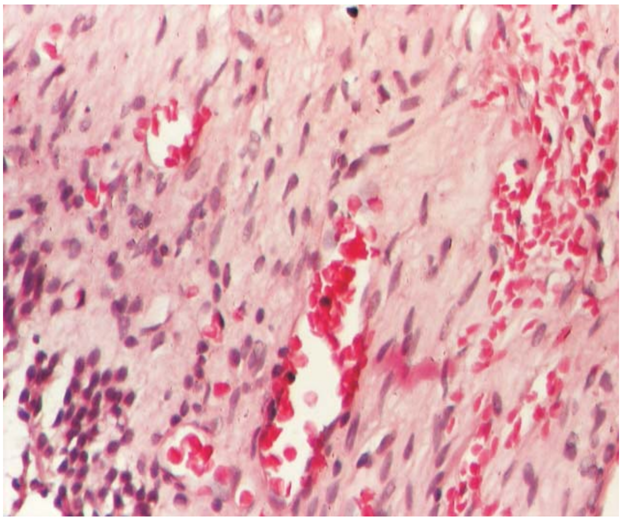

Figure 8 – ***Interstitial hemorrhages (HE, ×200)***

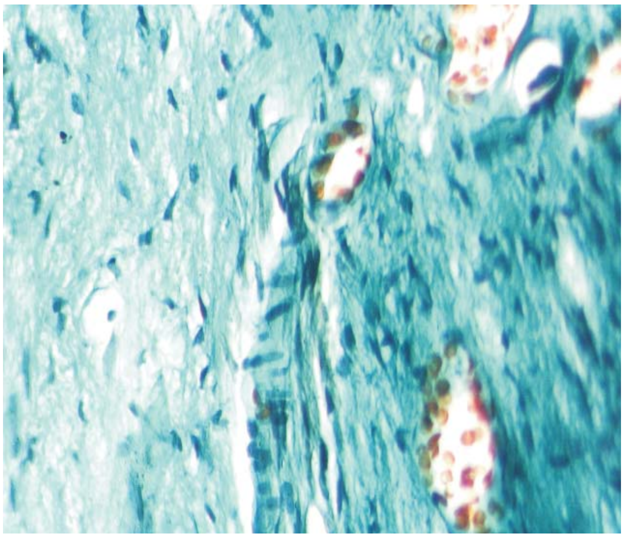

Figure 9 – ***Loose connective tissue with normal aspect (left) and densification tendency (right) (Szekelly, ×200)***

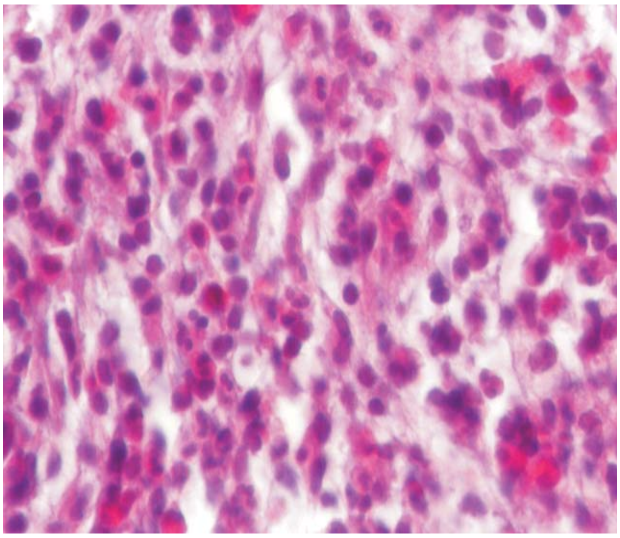

Figure 10 – ***Accute inflammatory infiltrate detail (HE, ×400)***

Another aspect in this group was a tendency towards densification of the connective tissue, in wide zones of the central pulp, alternating with loose connective tissue areas, appearing normal (Figure 9).

Although most of the times it is associated with an infectious (bacterial) agent, the presence of the inflammatory infiltrate (polymorphonuclears, lymphocytes, macrophages) (Figure 10) could be observed in this group, surrounded by numerous fibrocytes.

The existence of an inflammatory infiltrate in the pulp of a recently erupted sound tooth is a proof that the brutal thermal aggression represented by high-speed preparation without water-cooling can determine the apparition of an acute inflammatory process.

2. The pulp reactivity

The pulp immediate reactions to high-speed preparation can be classified in three groups:

▪ structural changes – the most important being the displacements of the odontoblastic nuclei into the dentinal tubules;

▪ vascular reactions – dilatations, decrease of blood flow and/or hemorrhages on wide areas, interstitial edema, vascular stasis;

▪ inflammatory reactions even in the absence of bacteria.

The displacement of odontoblastic nuclei and of the tubular contents, observed in this study and reported by some authors in the literature [3, 9-11, 22] can be produced by several mechanisms: overheating of the dentin during the teeth preparation, evaporation of the dentinal fluid from the prepared surfaces, the exposure of a high-pressure area by sectioning the tubules, excessive drying of the dentin by air cooling, mechanical distortion of the pulp-dentin complex during the teeth extraction.

The densification of the connective tissue and, as a result, the pulp fibrosis is phenomena appearing in the general context of aging. On the contrary, in the circumstances investigated by our study, these reactional changes are produced by the damages to the pulp, consequent to the activity of aggressive external factors [23].

The increase of pressure in the pulp, as a result of the exudate and the interstitial edema [12], may cause self-aggression for the pulp elements and, thus, the amplification of inflammatory phenomena.

Also, the high pulp pressure leads to compression of the venules, followed by the slowing down of the return circulation and venous stasis, determining the accumulation of toxic products from the metabolic processes.

The results of our study concur with those of About *et al.* [24] and Murray *et al.* [25] who noticed that the preparation of the dentin produced an inflammatory response in the absence of bacteria.

The pulp changes and the degree of inflammation corresponded with the depth of the preparation (inversely proportional to the thickness of the remaining dentin).

3. The thickness of the remaining dentin

Besides the utilization (or not) of water-cooling during preparation, the severity of the immediate pulp reactions depends on the thickness of remaining dentin as well (the depth of the preparation) [3]. Regarding the thickness of the remaining dentin, there are several opinions stated in the literature.

Thus, according to [26, 27] a minimum of 2 mm seems to be a critical factor in determining the pulp response and to guarantee the pulp vitality, if all the other prophylactic measures are taken.

It was experimentally demonstrated that very small variations in thickness of the remaining dentin have a significant influence on pulp reactions. Other authors consider that for the maintenance of the pulp vitality a 0.25-0.50 mm dentin thickness is appropriate [25, 28]. Zollner [5] demonstrated experimentally that, actually, the critical thickness of the remaining dentin must be ensured on the direction of the dentinal tubules opened by the preparation.

Irrespective of the mechanism involved, the results of this experiment showed that the displacement of odontoblastic nuclei occurs even in the case of a superficial preparation (0.4 mm) with water-cooling. The results of our study concur with those of [25, 28, 29] demonstrating that high-speed teeth preparation produces immediate pulp modifications even an adequate water-cooling is used. The severity of the changes is dependent on the thickness of the remaining dentin (the depth of the preparation).

4. Clinico-morphological correlations

Histologic and clinical experience showed that, although the pulp has a good regenerative potential, and the inflammatory response will often be followed by healing, the induced modifications can become significant on the long run [5, 22].

Thus, in the implementation of a treatment plan one must never start from the hypothesis that an asymptomatic tooth is a tooth with a healthy pulp. The scars following inflammatory and reparatory phenomena alter the resistance of the pulp to future injuries.

Regarding to the prosthetic fixed therapy, it is easy to be seduced by the technical possibilities and to forget the biological realities of the patient [30]. Recent developments in dental materials offer less destructive alternatives such as veneers, inlays and resin-bonded porcelain crowns.

The choice of a certain type of crown must be always in the patient’s best interest and depend on the functional requirements, strength and vitality of the remaining tooth and the aesthetic demands, as well the individual morphological characteristics of every tooth (the thickness of enamel and dentin layers).

Full metal crowns have the advantage of requiring a relatively superficial tooth preparation (0.4 mm), comparing with ceramic, composite, metal-ceramic and metal-polymeric crowns, that require a deeper preparation (1.5-2 mm) and thus are more destructive for the tooth structures.

A minimal preparation (only the enamel) is required in the case of resin-bonded porcelain crowns. Being the most conservative crowns for the tooth hard tissues, these are indicated especially in younger patients who have large, vulnerable pulp [31].

Conclusions

1. The dental pulp shows structural changes, especially in the odontoblastic zone, its reactivity being correlated with the depth and the technique of preparation.

2. In spite of all technical progresses in modern dentistry, there is no harmless, completely non-traumatic technique for the crown preparation. Histological changes in the underlying pulp occur anyway and are difficult to avoid as long as the crown preparation is performed at high speed, even if an adequate water cooling system is used.

3. Pulpal complications involving inflammation, degradation and necrosis are the result of a series of traumatic external injuries. So, it is the responsibility of the restorative dentist to minimize the trauma to dentin and pulp during all clinical procedures, especially in the tooth preparation phase.

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