https://doi.org/10.5272/jimab.2023291.4820
Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org
OPEN ACCESS
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Journal of IMAB. 2023 Jan-Mar;29(1)

Original article

# CLINICAL EFFECTIVENESS OF TITANIUM CAD/CAM RETAINERS FROM A BIOCHEMICAL POINT OF VIEW

Vladimir Petrunov
*Department of Orthodontics, Faculty of Dental Medicine, Medical University, Sofia, Bulgaria.*

**ABSTRACT:**

Following the integration of fixed retainers into the clinical practice, an increasing number of orthodontists prefer this retention method. Further to the proven advantages of those retainers, however, there are some deficiencies, which, if not taken into consideration, might compromise the good treatment result. CAD-CAM methods employ a different approach in design, materials and method of fabrication, and clinical procedures with respect to fixation. This allows for the avoidance of a large part of the deficiencies of the fixed retainers that are made manually.

**Aim:** Our aim is to demonstrate the clinical effectiveness of titanium CAD/CAM fixed retainers.

**Materials and methods:** Swing (DOF) Laboratory scanner was used to scan the models. Retainers were designed through Exocad Matera (Exocad GmbH) software. Retainers were fabricated of titanium Ti G5 (SILADENT Dr Böhme & Schöps GmbH) discs, machined with CORiTEC 650i (Imes-icore GmbH) 5-axis dental milling machine.

**Results:** The outcome is a retainer, which is excellently fitting to the dental surface, absolutely passive, resistant to plastic deformation, fracture-proof and with an extremely easy clinical fixing procedure.

**Conclusion:** CAD/CAM methods employ an innovative approach, providing a different manufacturing technology and the use of various materials for the purposes of fixed retention. These methods eliminate a significant part of the deficiencies of the conventional manually bent retainers.

**Keywords:** CAD/CAM, titanium G5, fixed retainer, relapse,

## INTRODUCTION

Orthodontic treatment has long ago been regarded not only as a means which provides normal occlusal relationship and ensures the normal functioning of the maxillofacial system. Increasing attention is paid to the aesthetic component and to the social effect of the treatment. That is to say, patients have particular requirements both with respect to a satisfactory extent of aesthetics and with respect to its longevity. On the other hand, orthodontists are well aware of how challenging it is to preserve the result obtained, which is sometimes a harder task than the achievement of the result itself. Over 70% of orthodontically treated patients more or less experience relapse [1]. Therefore, retention should be accepted as part of the treatment plan, and it is the orthodontist's responsibility to select the most appropriate retention method or a combination of methods. Lower front teeth are particularly susceptible to relapse. According to Little, only 10% of the cases were judged to have clinically and aesthetically acceptable alignment 20 years post orthodontic treatment [1]. In this regard, more and more patients opt for long-term or lifelong retainer wear, even when it is not required for medical reasons.

Various methods may be used to fight relapse: surgical, gnathological, and biological, but mechanical methods have gained the recognition of being sill the most effective ones. Typically for these methods, the retention appliances enable the post-treatment alignment of the teeth to be retained until processes needed to keep the stability of this alignment take place. Since as early as 1967, Reitan determined a period of 232 days as the critical minimum for the length of the retention period – the time necessary for the reorganisation of the periodontal fibre system [2]. However, when other factors, such as the severity of the malocclusion, treatment time, growth, etc. are taken into consideration, the retention period may be significantly extended. Currently, there is a great variety of retention appliances, but generally, these can be divided into two basic groups – removable and fixed appliances. There is no ideal retention appliance. Each group has its own pros and cons related to patient cooperativeness, oral hygiene, comfort, treated malocclusion, etc. Therefore, the orthodontist is faced with the responsible task to select the most appropriate retainer for their patient's particular case.

As adhesive technologies in dental medicine develop, in the 1970s the use of fixed retainers was employed. Ever since they have continued to gain increasing popularity among orthodontists [3]. A summary of their major advantages includes good aesthetics because the appliances are usually situated lingually, good tolerance by the patient, comfort, and good retention function in the single dental arch. Their primary advantage, however, is that no cooperativeness on behalf of the patient is required. The major disadvantages are related to particular difficulty in maintaining oral hygiene, the possible detachment of a tooth from the retainer which may further migrate, the risk of plastic deformation of the retainer that can result in tooth displacement. Fixed retainers may differ in the type of material they are made of. There are retainers consisting of a piece of orthodontic wire adjusted to the lingual tooth surface, bonded to the canines and manually twisted multistranded wire lingually bonded to all anterior teeth [4]. Pre-fabricated lingual retainers may be of the flexible chain [5], manufactured flattened multistranded wire or rigid wire, ending in both ends like a bracket base for easy fixation [6].

The increased integration of CAD/CAM technology into dental medicine and orthodontics made it possible for fixed retainers to be manufactured under this method. CAD/CAM methods are related to the generation of a digital work model, typically in terms of intraoral or laboratory scanning [7], digital design of the construction with CAD software [8] and a CAM method of the retainer manufacturing with the help of computer numerical control machines through a subtractive production method, i.e. milling [9] or through additive production – 3D printing [10]. These approaches alter the structural concepts based on the new materials used in the digital mode of design and fabrication.

**AIM:**

This article aims to demonstrate the clinical effectiveness of the titanium CAD/CAM fixed retainers and their advantages over the conventional ones from the perspective of their biomechanical properties.

**MATERIALS AND METHODS:**

Retainers were made through CAD/CAM methods. Swing (DOF) Laboratory scanner with a 1.3-megapixel camera was used to prepare the digital model. Following the generation of the STL file from the model, we used dental technician CAD software, EXOCAD – Matera (Exocad GmbH). Retainers were fabricated of titanium Ti G5 (SILADENT Dr Böhme & Schöps GmbH) discs, machined with CORiTEC 650i (Imes-icore GmbH) 5-axis dental milling machine. Then we bonded the retainers with Tetric EvoFlow flowable light-curing composite by Ivoclar Vivadent AG.

**RESULTS:**

The use of CAD/CAM methods for the retainer fabrication results in a product which is far most different from the retainers made through the conventional manual methods (Figure 1). The retainer fits precisely along the entire tooth surface. Digital design allows the fabrication of a complex geometric shape with bends in all three planes. Exact parameters of the construction could be set, such as thickness and width. CAM methods ensure the precise reproduction of the designed shape, and the technological requirements and tolerances are strictly met. The retainer is absolutely passive. This, along with its precision, facilitates the fixation process, eliminating the need for a transfer tray or preliminary fixation of the retainer with ligatures. When a new retainer is needed, it may be fabricated from the saved file, and 100% replication of the shape is guaranteed.

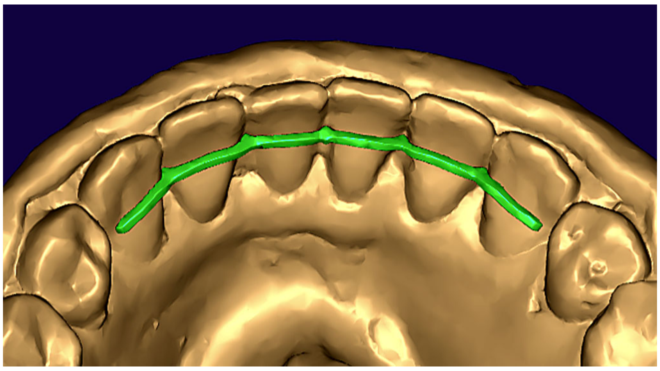
**Fig. 1.** Titanium CAD/CAM retainer, fixed to the teeth

**DISCUSSION:**

To retain the orthodontic treatment result is not at all less responsible than to achieve it. The orthodontist is the one to opt for the most appropriate retainer for any particular patient and clinical case. This requires good knowledge of both indications and materials and clinical procedures. Conventional fixed metal retainers are most often made of an orthodontic wire, multistranded twisted wire or of a flexible chain. The first two methods require particular manual skills for the proper fitting of the retainer to the tooth surfaces. In the third method, the fixing of the retainer is related to a much more complex procedure. The digital working protocol and the CAD/CAM methods provide new possibilities, both clinical and technological. Intraoral or extraoral scanning may be used to obtain the digital model. The first one has more advantages such as reduced clinical time [11] and is more suitable for cases where brackets have not yet been removed. The option of digitally designing the retainer shape and outlines allows for freedom and precision, which are not possible to achieve with the manual bending of the retainers (Figure 2).

To demonstrate the advantages of these retainers, we will make a brief review of some biomechanical features of fixed retainers.

**Fig. 2.** Digital design of the retainer



*Problems related to conventional fixed retainers.* The round wire intended for the fabrication of retainers allows bending in all directions with equal ease. This would facilitate the adjustment of such a retainer not only in the horizontal plane along the dental arch, but it would also enable bending in a vertical direction to adjust the retainer along the height of the tooth crown. This is particularly important for the bending of the retainer in the upper dental arch, as in that place the contact with the lower anterior teeth must be avoided. In modern practice, round-wire retainers are made of Penta-One steel multistranded (five-stranded) retention wire with a diameter of 0,0215" and 0.0195", or Twist Flex 0.0178". The bending of such a wire, however, has its specifics. The multistranded wire is much more elastic than the single stranded one, which makes its bending difficult. Such a wire has to be bent in a way that follows the dental arch, but at the same time, it should not strictly follow the outline of the tooth surface. This retainer is bonded with composite in the middle of the incisor's lingual surface. If the retainer follows tightly the tooth surface, then the arch between two fixation points is longer than the distance in a straight line between these points (Figure 3). As this wire type is not so rigid, it enables slight tooth movements such as slight rotations or opening of small distances between the teeth. Therefore, the lingual retainer has to be bent in a way that does not follow the pattern of the anatomic tooth surfaces (Figure 4). This, in turn, causes another problem. When the lingual teeth surfaces are more concave in the spots of the approximal contacts, a greater distance between the tooth surface and the retainer is formed. For this reason, the retainer withstands a higher load under the effect of the masticatory forces. This is a prerequisite for the debonding of the retainer from the tooth surface [12], fracturing as a result of the masticatory forces or activation of the retainer, which could cause the twist-effect described below [13]. Another problem, originating from the same fact, is related to the maintenance of good oral hygiene, which is anyway impeded in fixed retainers [14]. The greater distance between the retainer and the tooth surface at certain places provides for the collection of food debris in these spaces. There is a risk of debonding the retainer when attempting to clean them, most often with interdental brushes.

**Fig. 3.** Diagram of a retainer which is bent following the tooth shape. The green line indicates the distance between the fixation points. The red curve shows the perimeter of the wire between the fixation points.

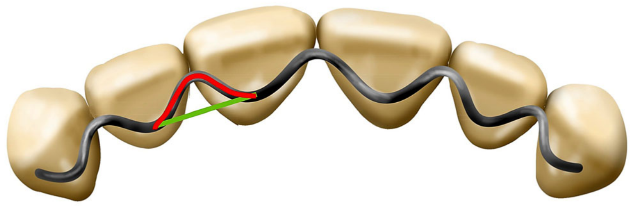
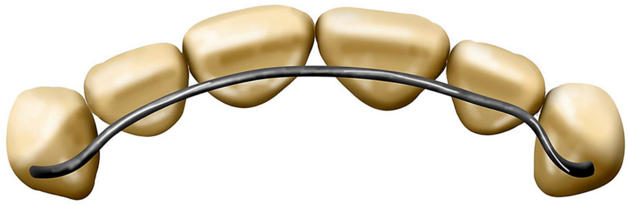
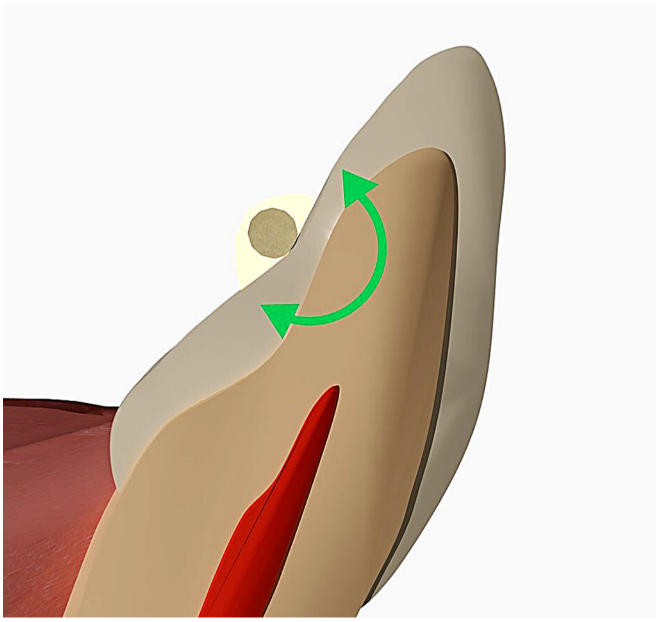


**Fig. 4.** Diagram of a retainer, which is bent along the dental arch without following the tooth shape.



Other adverse effects of these retainers are the X-effect and the twist-effect [13]. The X-effect is the change in the vestibulo-lingual tipping of two adjacent teeth one towards another. It may be anticipated for teeth where the torque has been significantly changed during the treatment process. The reason is the so-called 'tunnelling effect' – the round-wire retainer allows movement of the tooth around the retainer axis (Figure 5) and the tooth is tipped buccolingually with a centre of rotation along the longitudinal retainer axis. The second effect is the opposite tipping of contralateral canines (the first one lingually, and the second vestibularly) with torqueing of the whole anterior segment. The curious fact is that teeth are not displaced towards their initial position and this movement shall not be regarded as a relapse. The reasons for this effect have not been fully explained yet. It is considered that the most common ones are activation of the bent retainer before its fixing, or activation of the retainer while fixed on the teeth and displacement of some of them under the effect of the masticatory forces, resulting from primary contacts.

**Fig. 5.** The round profile of the retainer could cause rotation of the tooth around the retainer – 'tunnelling effect'.



The rectangular or oval profile wire is used to compensate for both effects. Even if we use the same materials for both the round- and rectangular-profile wire, the rectangular profile wire will be more resistant -to deformity. Furthermore, as this wire prevents the occurrence of the tunneling effect, the possibility of the X-effect is very little. The problem related to this wire shape is, that it is easily bent along its small cross section, but significantly harder along its large cross section. Thus, the bending of the retainer in occluso-apical direction is significantly restricted. Such bends are of paramount importance for the adjustment of a fixed lingual retainer in the upper dental arch, where contacts with the lower anterior teeth have to be bypassed. During the manual bending of a multistranded wire retainer, because of the significant difference in the vestibulo-oral dimensions of the lateral incisors and the canines, it is often necessary to make a step bend between these teeth. This is the exact point where fracturing of the retainer most often occurs. The reasons are stress in the material caused by the bending on the one hand, and the greater distance between the fixation points on the other hand.

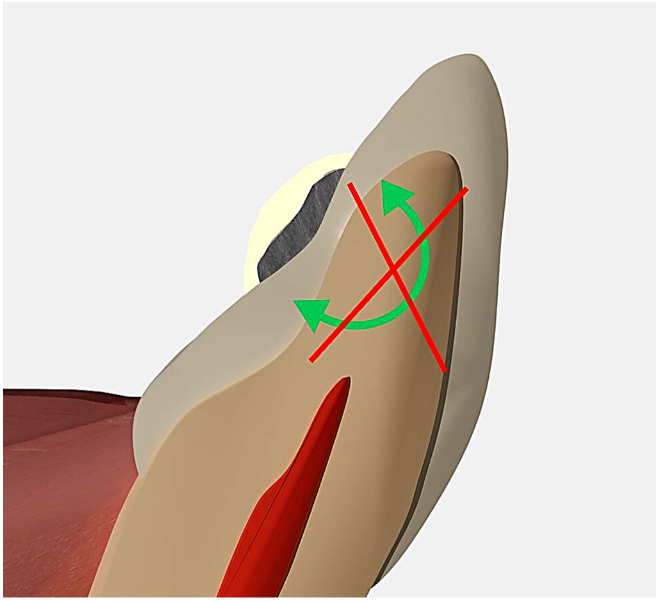
Another problem that exists in multistranded wire retainers is related to their fixation. They do not fit completely tightly to the lingual tooth surface. Therefore, indirect bonding methods are required or fixing the retainer in advance with ligatures or dental floss [15]. The first option is related to the additional laboratory stage, which raises the cost. The second option hides a risk of gingival bleeding if the operation with ligatures is not too precise and careful. The adhesive bonding of the retainer could then be problematic. Besides, as it was mentioned above, multistranded retainers possess some elasticity, and if not fixed passively, there is a risk of deformation during fixing. Sifakakis et al. found, that 0.2 mm deformation of the retainer wire is enough to generate the force necessary to cause tooth movement [16]. Seide et al. establish in their study that the wire windings of the retainer after fracturing could generate forces caused by the wire unwinding tendency. According to the authors, from this point of view, the round triple-stranded retainer wires are at higher risk to induce inadvertent side effects [17]. In addition to tooth displacement, the active retainer may be the reason for gingival recesses in mandibular anterior teeth [18].

There is no risk of activation before and during the fixation of the chain-type retainers. Because of their plasticity, however, the fixing procedure is much more time-consuming. This is a prerequisite of imbalance of the dryness of the operational field, which could result in debonding.

Considering the above specifics of the manually bent and adapted retainers, it is apparent, that to ensure the success of such a procedure, the dental doctor's experience and good skills are an important factor. CAD/CAM methods for the fabrication of fixed retainers offer a completely different approach.

*Advantages of titanium CAD/CAM retainers.* As soon as we have in place a digital working model, it is transferred to the CAD software and is then proceeded to the digital design of the retainer borders. During the design, the adjustment of the retainer to the tooth surface with respect to the three planes is completely trouble-free, which is hard to achieve in manual bending. The retainer profile is elongated, and not round, which counteracts both the X-effect and the twist-effect (Figure 6). Another typical difference is that when bent from a fabricated wire, the retainer is equally thick and wide along its entire length. The digital design of the retainer allows for its thinning at particular places, for instance for the purpose of avoiding tooth contacts, or thickening in critical areas where the most frequent fracturing place is. The CAM fabrication of the retainer is in terms of 3D printing or milling. The retainer produced via both methods is fully passive, as it is made in the designed shape and no additional deforming forces were applied thereupon. This is very important in view of the above mentioned adverse effects of the activated retainers. The adapting of the retainer following the tooth shape is of no risk of slight tooth movements as the CAD/CAM retainers are more rigid compared to those bent of a multistranded wire. At the same time, for the post-treatment fixing of teeth in the long run and for their splinting it is important that the retainer is not too rigid and that is allows particular individual tooth movements [19]. Titanium G5 is a suitable material for this purpose because it possesses a lower elastic modulus compared to the Co-Cr alloys.

**Fig. 6.** The elongated retainer profile prevents the possibility of rotating the tooth around the retainer.



And last, but not least, owing to the excellent fitting of the retainer to the tooth surface when fixed, no use of transfer trays is required, nor legation with ligatures and dental floss. The use of a small amount of flowable composite in the bonding area is sufficient to retain it on the tooth surface thanks to the viscous properties of the composite. Thus absolute inactivity during the fixing procedure is ensured.

**CONCLUSION:**

CAD/CAM methods offer a completely different approach to the fabrication of fixed retainers. Digital design allows variation in the profile, size and thickness of the retainer. The CAM-methods of fabrication guarantee high precision and inactivity of the end product, irrespective of the complexity of its shape. Titanium G5 is a material with excellent properties for the fabrication of long-term fixed retainers. The CAD/CAM-made titanium retainers offer excellent fitting along the tooth surface, they are absolutely passive and resistant to plastic deformation, fracture-proof and the clinical procedure for their fixing is extremely easy.

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*Please cite this article as:* Petrunov V. Clinical Effectiveness of Titanium CAD/CAM Retainers from a Biochemical Point of View. *J of IMAB.* 2023 Jan-Mar;29(1):4820-4825. DOI: https://doi.org/10.5272/jimab.2023291.4820

Received: 02/11/2022; Published online: 14/02/2023

**Address for correspondence:**
Vladimir Petrunov
Department of Orthodontics, Faculty of Dental Medicine, Medical University - Sofia,
1, Georgi Sofiiski Blvd., Sofia, Bulgaria.
E-mail: dr.petrunov@mail.bg,