Mechanical properties of different types of space maintainers

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Abstract. Currently, inside the oral cavity, the dental space maintainers are subjected to forces exerted on them when performing various functions; therefore, it is important to know how each of these mechanisms behave and respond to forces that are applied directly to them. The mechanical properties of the materials used in dentistry are defined by a set of characteristics representing the behaviour of their particular working conditions and it is qualitatively expressed by a number of parameters. The study aimed to determine the pressing force that can be taken by four 4 types of space maintainers frequently used in practice - fixed and removable, applied on four samples realized with human teeth extracted for orthodontic purposes. Static tests were carried out on a machine type short WDW-5 EC with a maximum force of 5 kN and a loading speed of 5 mm/min by a special testing machine, with an innovative appliance; data recording was automatically performed, using a computer with a special program that present the specific diagrams. Experimental determinations included the following aspects: to determine the maximum force that can be supported by each sample, and to observe the deformations. The values obtained indicate that the best option in terms of behavior under the conditions specified is the removable appliance, and the less functional version is the fixed space maintainer using brackets. According to tests conducted, the fracture strength was found to be more important for fixed space maintainers (band and loop, for example) so, in practice is using more frequent these types of space maintainers.

1. Introduction
Currently, into the oral cavity, the dental space maintainers are subjected to forces exerted on them when performing various functions; therefore, it is important to know how each of these mechanisms behave and respond to forces that are applied directly to them. The mechanical properties of the materials used in dentistry are defined by a set of characteristics representing the behaviour of their particular working conditions and it is qualitatively expressed by a number of parameters. The
determination of mechanical characteristics/properties uses a special machine, for testing the corresponding goal, aiming the behaviour of samples and records breaking, following the characteristic parameters and analyzing both the way and breaking appearance.

Mechanical tests of strength of materials - tensile or compressive - make it possible to track the behaviour and characteristic parameters diagrams expressing the relationship between the applied forces and specific corresponding linear deformations. [1]. In order to determine the resistance of the materials to dynamic loading, are widely used the bending impact tests, known as the resiliency tests. Under the action of forces, the samples are deforming and moving those points; it has been shown that the values of movements caused by the deformation of the sample are generally small compared to the size of the sample - is allowed so that by deforming, the sample changes its shape and original size, in a relatively small extent. Small deformations are usually elastic deformations, which disappear with the disappearance of the forces applied. Between the applied forces and displacements produced and between internal efforts and deformations of the sample, there is a close relationship expressed by mathematical relations - the elastic movements of these samples are proportional to the forces applied - this observation expresses Robert Hooke's law. Thus, we can write:

\[ \Delta = \delta \ast P \]  

where: \( \Delta \) is the displacement of any point caused by force \( P \), \( \delta \) is a coefficient of "influence", which represents the movement of point \( P \) considered under a force equal to unity. The magnitude of this coefficient depends on the material, shape and size of the sample, the strength and position of the point considered.

Tensile and compression tests run on special machines that perform axial strain of the sample. From the simplest machines, mechanically operated via a lever system, and till the universal testing machines with many possibilities, there are a variety of systems, from small forces developing for several daN, to those that perform forces as thousands of kN. At any time during the test, it can be register the elongation \( \Delta l \), corresponding to the axial force \( N \) applied to the sample. Than, by plotting the pairs of values obtained during the test, there can be drawn the characteristic curve tensile of the sample. The behaviour of a sample under the action of external forces can be described by the stress-strain curves obtained in tension, compression, torsion, etc. Building a diagram type real tension-real strain, tension grows continuously until rupture, and the actual curve is called tension-deformation [2].

2. Materials and method

The study aimed to determine the pressing force that can be taken by four 4 types of space maintainers frequently used in practice - fixed and removable, applied on four samples realized with human teeth extracted for orthodontic purposes. Static tests were carried out on a machine type short WDW-5 EC with a maximum force of 5 kN and a loading speed of 5 mm/min by a special testing machine, with an innovative appliance; data recording was performed automatically, using a computer with a special program that present the specific diagrams. Experimental determinations included the following aspects: to determine the maximum force that can be supported by each sample, and to observe the deformations, (figure1).

Data recording was performed automatically using a computer which takes the data from each stage of force and forward them to be viewed in the diagrams illustrating the variation curves of the pressing force depending on the strain, respectively, versus time. The samples were tested until the pressing force has reached the maximum value or until the destruction of the sample.

The test samples were performed on extracted human teeth for orthodontic purposes - premolars and third molars (in order to simulate the second temporary molar); extracted teeth were introduced into a mass of acrylic resin, which represent the support for each of the samples. At the level of each of the samples, respectively simulating the edentulous space, by the absence of deciduous tooth, it was applied fixed or removable space maintainer, (figure2, figure 3).
For the types of fixed space maintainers, fixed orthodontic rings were chosen in a series of rings supplied by Ormco®, and have been adapted on the teeth. Wire loops were made from 1.0 Dentaurum® wires, and welded in a dental laboratory [3].

**Figure 1.** The type of curve recorded for 5 kN force and speed of 5 mm/min.

**Figure 2.** Performing the samples of space maintainers.

**Figure 3.** The samples (space maintainers) applied on a special support of the testing machine WDW-5 CE.
3. Results and discussions
For each sample, we obtained diagrams of force variations in kN depending on the stain (in mm), versus time (in seconds). So, for first sample, a fixed appliance (brackets), according down force applied, the chart is redrawn to deformation (0.04kN). For the removable space maintainer, the diagram is an ascending one according to force applied (0.42kN), until the fracturing moment; this was the type of space maintainer that had the weakest response to maximum force, (figure 4, figure 5).

![Figure 4](image1.jpg)
Figure 4. Diagrams obtained after application of different forces for the first sample, with fixed orthodontic space maintainer.

![Figure 5](image2.jpg)
Figure 5. The force applied on the first sample and the diagram of force and deformation.
Figure 6. The force applied on the second sample (band and loop) and the diagrams of force and deformation.

Figure 7. The force applied on the third sample (fixed regaining space orthodontic device) and the diagrams of force and deformation.
Studies regarding the mechanical behaviour and properties of different types of devices used as space maintainers are rare. There are no scientific studies to evaluate the fracture strength and the effects on space maintainers, both devices made in the laboratory and those prefabricated provided by various manufacturing companies. Krishnan et al. (2004) evaluated in one trial, three types of springs used in the manufacture of orthodontic devices - stainless alloy, titanium beta-timolium, and found that the resistance to fracture differ significantly between the three materials. Although there is, in this study a comparison with the initial evidence, it can be assumed that exist a significantly lower fracture resistance. Babe et al. [4] conducted a study on the fracture strength of orthodontic appliances made in the laboratory, showed the items that were fixed by welding (such as space maintainers - ring and loop, and loop crown cover). The study showed a lower resistance to deformation than the controls, values were not significant.

A recent study showed a greater resistance to bending orthodontic devices using springs, with the following values: Ti - 18% NiCr - 66% and CoCr - over 69%. Testing and fracture resistance appear to be comparable to interlock welding/brazing bands and crowns elements [5].

Further researches are necessary to determine optimal parameters for each device, and to achieve solidarity in particular, for types of space maintainers such as bands/crowns and orthodontic loops, which are the most used fixed appliances, to maintain the edentulous space arrangements until the permanent tooth eruption, (figure 7, figure 8).

| Sample | 1     | 2     | 3     | 4     |
|--------|-------|-------|-------|-------|
| Loads  | 0.04 kN | 0.26 kN | 0.04 kN | 0.42 kN |

4. Conclusions

The values obtained indicate that the best option in terms of behavior under the conditions stated above is the removable appliance (sample no.4) and the less functional version is the fixed space maintainer using orthodontic brackets (sample no.1). Very similar values are reported for space maintainers consist of orthodontic band and loop, respectively orthodontic rings and double loops. The results of tests carried out are fully consistent with those known from the literature.

According to tests conducted, the fracture strength was found to be more important for fixed space maintainers made of orthodontic band and loop, and orthodontic rings with slider, resulting in more frequent use in practice these types of appliances.

Despite the low resistance, removable space maintainers made from acrylic resins are commonly applied to treat toothless transient (temporary dentition and mixed dentition), because, most often,
orthodontic appliances included these removable devices, are recommended to treat various malocclusions, common in these age stages.

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