Chapter 6

Anatomical and Functional Restoration of the Compromised Occlusion: From Theory to Materials

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Abstract

Many conditions can alter the occlusal interface, from tooth wear to tooth loss. The masticatory system is constituted by many components that can influence each other like muscles, joints, teeth and nervous system. This implies that (a) every change at occlusal level makes the other components to adapt and (b) an occlusal alteration may be the effect of an alteration occurred on muscles or joints. Keeping this in mind, traditional principles of occlusal rehabilitation are analysed, and the choice of the restorative materials is discussed.

Keywords: dental ceramics, freedom in centric, lithium disilicate, masticatory system, occlusal morphology, occlusion

1. Introduction: Occlusal disorders

Many conditions or pathologies can affect dental tissues and therefore alter the occlusal interface, like dental caries, trauma and tooth wear. The latter one indicates the surface loss of dental hard tissue from causes other than developmental ones, dental caries and trauma [1]. It is a very complex phenomenon, including processes of different origin such as erosion, attrition and abrasion [1, 2]. Wear is a normal physiologic process and occurs throughout life, being part of the aging process [2]. A degree of tooth wear is considered unavoidable [3]. Problems arise if the rate of loss or the degree of destruction becomes excessive, exceeding the physiological mechanisms designed to compensate for it (e.g. formation of secondary dentin and eruption process [4]). In this manner, it may cause functional or aesthetic problems or sensitivity for the patient [5], or it is likely to prejudice the survival of the teeth [6] or it reaches a level at which restorations are indicated [2]. Furthermore, wear could lead to poor masticatory function with a concomitant reduction in quality of life and possible deterioration of systemic health [7]. Such a wear is called *pathological* (**Figure 1**) [8]. With increasing life expectancy and more people keeping their natural dentition into old age, the problems associated with tooth wear are likely to place greater demands upon dental professionals [1].

1.1. Attrition

Attrition is the physical wear of tooth against tooth, which means that (a) it is strictly related to occlusal relationship and (b) only tooth surfaces that make contact with each other can be described as having attrition (**Figure 2**) [9]. Regarding the mechanism of action, attrition is

Figure 1. Extensive, pathological tooth wear due to attrition.

Figure 2. Dental attrition is strictly limited to occlusal/incisal surfaces.

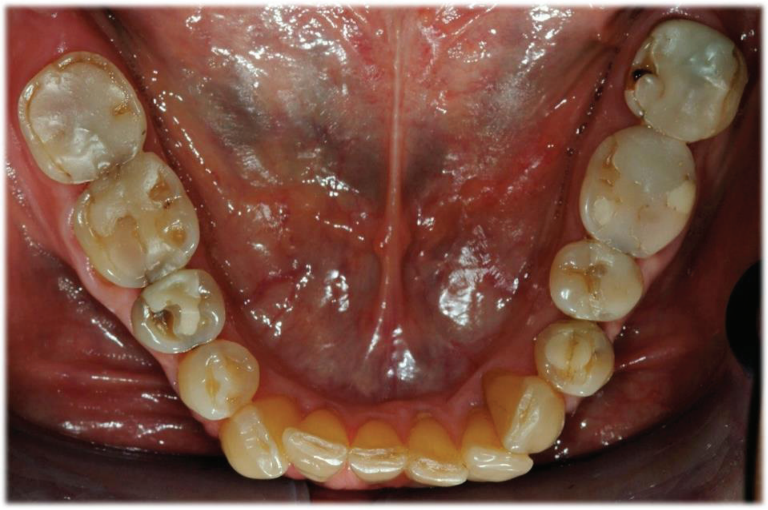

Figure 3. Dental abrasion may involve the entire dental surface.

a two-body wear process. The exact prevalence of attrition is unclear primarily because of differing assessment criteria [5, 6]. Data from literature vary greatly [9]. However, we certainly know that some para-functional activities can contribute greatly towards attrition [10]. Among these, grinding teeth during sleep or awake can dramatically accelerate tooth attrition. Also, the presence of restoring material harder than dental tissues may intensify the rate of attrition.

1.2. Abrasion

Abrasion is the physical wear of the tooth surface by something other than another tooth, like foods and toothbrush. It affects the entire tooth surface rather than just the occlusal contact area (**Figure 3**).

Figure 4. Dental erosion typically does not involve restorations.

1.3. Erosion

Erosion is the result of chemical dissolution by acids, excluding chemicals produced by bacteria. Acids may be exogenous (acid foods and beverage- lemon, cola, etc.) or endogenous (gastric reflux or vomit). Typically, restorations are not affected (**Figure 4**).

2. Restoring the occlusion: not just teeth

In restoring the occlusion, it is fundamental to keep in mind that the masticatory system is constituted by different components such as occlusal interface, masticatory muscles, temporomandibular joints (TMJs) and nervous system (central and peripheral, motor and sensory). All the components can influence each other. This statement has two implications. First of all, a change in occlusion will have consequences on the rest of masticatory system that needs to be adapted. In physiological condition, the system has the ability to adapt to changes, like any other biological systems [11]. As dentists, we act on occlusion, but de facto, we act on the entire masticatory system. On the other hand, that means that alterations in one of the other components of the system may be pointed out as occlusal alteration. For example, in the case of muscle pain, it was shown that the distribution of occlusal contacts changes [12]. In that study, an experimental muscle pain was induced in masseter in healthy subjects. Even if the number of occlusal contacts did not change, the distribution did. After the pain resolution, the distribution of contacts returned to baseline. In other words, muscle pain (and, more generally, facial pain) influences muscle activity in a specific way, altering the position of the mandible and, as a consequence, the occlusion. This is consistent with the so-called 'pain-adaptation model' [13]. Accepting this model has important practical consequences, first of all, the end of 'occlusal adjustment' as therapy for muscle pain. For decades, in fact, it was assumed that the so-called occlusal interferences were the most frequent cause of masticatory muscle pain: the masticatory muscles would be enrolled to eliminate the occlusal disturbances and this 'hyperactivity' would cause muscle pain. Of course, eliminating the occlusal interferences would stop the muscle activity and, so, the pain. On the contrary, as demonstrated, the 'occlusal alterations' can be the effect rather than the cause of muscle pain; touching the occlusion of a suffering patient may result in an irreversible and a useless damage. This aspect is confirmed also in treating patients with muscle pain; they often complain that their teeth 'no longer fit together properly' [14].

The second clinical implication regards the establishing of intermaxillary relationship; to correctly establish the position during rehabilitation, the masticatory system is needed not to be in pain. Otherwise, the pain would alter the muscle activity and, consequently, the jaw position, leading to an error in the choice of horizontal relationship (see below). This may happen regardless of the technique used to achieve the centric position. Obrez and Stohler [15] found a difference in the position of the apex of the Gothic arch (i.e. the centric position) before and after a muscle pain was experimental induced in the masseter. The difference disappeared after the pain resolution. So, any registration of maxillomandibular relationship, and thus any occlusal rehabilitation, cannot be achieved until the pain condition has been resolved.

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Also, an alteration at TMJ level may be firstly seen at occlusal level. In the case of TMJ inflammation, a swelling of synovial space may occur, resulting in the excessive intracapsular fluid. This phenomenon may cause a so-called acute malocclusion, which is a premature contact of anterior teeth with disclusion of the posterior teeth [16]. The malocclusion disappears after resolution of TMJ inflammation. Also, chronic pathologies affecting TMJ may lead to secondary malocclusion, though it develops slowly and can be easily underestimated. Such a scenario happened in a patient suffering of systemic rheumatoid arthritis with a bilateral TMJ involvement. The massive erosion of both mandibular condyles leads to a secondary, progressive anterior open bite (**Figure 5**).

The following case represents the best example of the diagnostic error that may result from looking just at the occlusion, forgetting the other components of the masticatory system. The patient showed a facial asymmetry with a left cross-bite (**Figure 6**). Many clinicians proposed to him to orthodontically and/or orthodontically correct the cross-bite. The clinical examination showed left buccal wear facets that were incompatible with the cross-bite. Dental casts were able to get the maximum intercuspation, so an obstacle in the contralateral TMJ was hypothesized. Indeed CT exam showed a mass in the right TMJ (**Figure 7**). The histological examination resulted in osteoma of the glenoid fossa that was surgically removed restoring the occlusion without any other occlusal therapy (**Figure 8**) [17]. The former was certainly an extreme case, but it suggests that a joint problem may cause an altered centric. So it is always necessary to evaluate not only masticatory muscles but also TMJs. More extensively, whenever you need to completely rehabilitate the occlusion, it is an essential overall assessment of the masticatory system and not only of the dental condition.

The term 'neuroplasticity' refers to the adaptive ability of the brain to undergo structural and functional changes throughout the life. These changes are fundamental for the acquisition of

Figure 5. Anterior open bite due to degenerative arthritis of mandibular condyles.

Figure 6. Left cross bite.

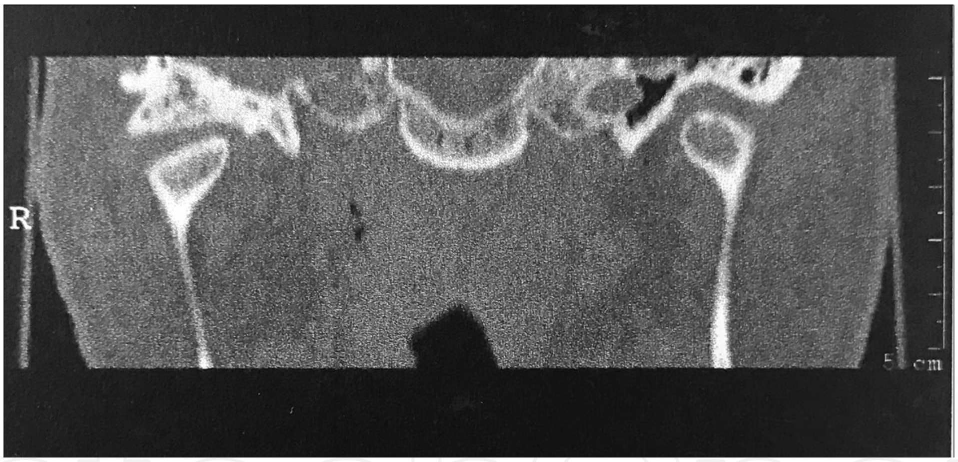

Figure 7. CT scan showing a mass in the right glenoid fossa dislocating the mandibular condyle.

motor skills, memory, development of the central nervous system (CNS), learning and adaptation resulting from nerve trauma or other sensory changes. The CNS is a plastic system: neuroplasticity allows us to survive to environmental challenges. Luraschi et al. [18] found that, after the insertion of a new complete denture, the CNS responded with the activation of cerebral cortical areas that were previously silent (showed with functional magnetic resonance imaging); after a period of 3 months they returned to baseline. In other words, cortical neuroplastic changes occur in association with adaptation to changes at occlusal level. These findings lead to a fascinating perspective on explaining why some subjects easily adapt to changes while others failed [19].

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Figure 8. Resolution of left cross bite after surgical removal of the osteoma in the right TMJ.

2.1. The principles of restoring the occlusion

Many years passed since Beyron enunciated his principles to achieve what he poetically called 'occlusal harmony' [20, 21]. These principles included:

- acceptable vertical dimension of occlusion (VDO) with acceptable interocclusal distance
- stable jaw relationship with bilateral contact in retrusive closure
- freedom in the retrusive range with maximum intercuspation slightly and straight in front of the retruded contact position
- axial occlusal contacts on the posterior teeth
- no interference in eccentrics movements

Even if little or no evidence was provided over the years for supporting those principles, they are inspired, now as then, by common sense, appearing wise and cautious, and, in the authors' opinion, they are still valid.

2.2. Establishing the vertical dimension

Restoring the occlusion very often means restoring the vertical dimension. The vertical dimension of occlusion (VDO) is defined as the distance measured between two points when the

Figure 9. The same patient before (on the left) and after restoring the correct vertical dimension.

occluding members are in contact with each other [22]. Many methods have been described to establish the correct VDO. These methods are often combined to achieve the best result. However, even if some methods pretend to be more 'scientific' or 'validated' than others, establishing the VDO remains a clinical manoeuvre, in which the clinician's personal talent and experience play a crucial role.

For establishing the correct VDO, we employ three consecutive methods such as rest position, phonetics and aesthetics. We usually start from the physiological rest position of the jaw [22], when the head is in an upright position, there is no dental contact, antagonist muscles (jaw elevators and depressors) are balanced and the mandibular condyles are in a non-forced position in the glenoid fossa. In this position, an 'interocclusal distance' of few millimetres is present, i.e. antagonist teeth are not occluding. If during rest position, antagonist teeth are in contact, the VDO may be too high and it needs to be reduced.

The rest position is the starting point to determine the new VDO, but it must be combined with other functional aspects, first of all with phonetics. If the VDO is incorrect, phonetics may be negatively affected. Pound established that the key to the ideal relationship between antagonist anterior teeth for achieving clarity of speech was the 'S position'. The 'S position' is defined as the most forward position the mandible ever assumes during speech and it is the closest to contact of any teeth during a speech [23]. The 'S position' limits the possibility of increasing VDO, as an excessive VDO will cause antagonist teeth contact during 'S' sounds.

The final aspect to consider is aesthetics. The dimension of the lower third influences the overall appearance of the patients' face, so aesthetic considerations have a key role in defining VDO. Restoring the lost VDO may give several years back to the patient, removing the old appearance that the lost teeth and the lost dimension usually cause (**Figure 9**).

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2.3. Choosing the 'therapeutic position'

In case of gross occlusal alteration, it is necessary to choose a therapeutic position of the mandible in which the new 'centric occlusion' is created. Few arguments have been debated in the past and present of dentistry, like the choice of therapeutic position. Independently from the 'philosophy' that guides you, the definitions of centric and the method to assess it are closely related, and so the consequent occlusal morphology. Some authors prefer to actively guide the jaw in the centric relation, and various manoeuvres have been described [24]. Other authors prefer not to 'force' the jaw in a specific position. One 'not guided' method consists in choosing a retruded functional position as shown by tracing the border mandibular movement on the horizontal plane. This method, called 'central bearing point', was initially created for complete denture rehabilitation, but it may be adapted to every clinical situation. A pivot traces jaw movements on a plate, designing the so-called 'Gothic arch' (**Figure 10**). The apex of the Gothic arch represents, in this approach, the centric relation (**Figure 11**). This centric relation may be chosen as reference position in creating the new centric occlusion, ensuring a 'freedom in centric' as explained below.

2.4. Designing the occlusal anatomy

Old studies showed that functional movements do not occur in a single position, but in an 'area' around the centric occlusion [25]. This is the biological premise for the so-called '*freedom in centric*' in which there is a degree of freedom in centric movements starting from the central fossa of the occlusal surface [26]. This concept avoids interference on posterior teeth during functional movements, that is, one of Beyron's principles.

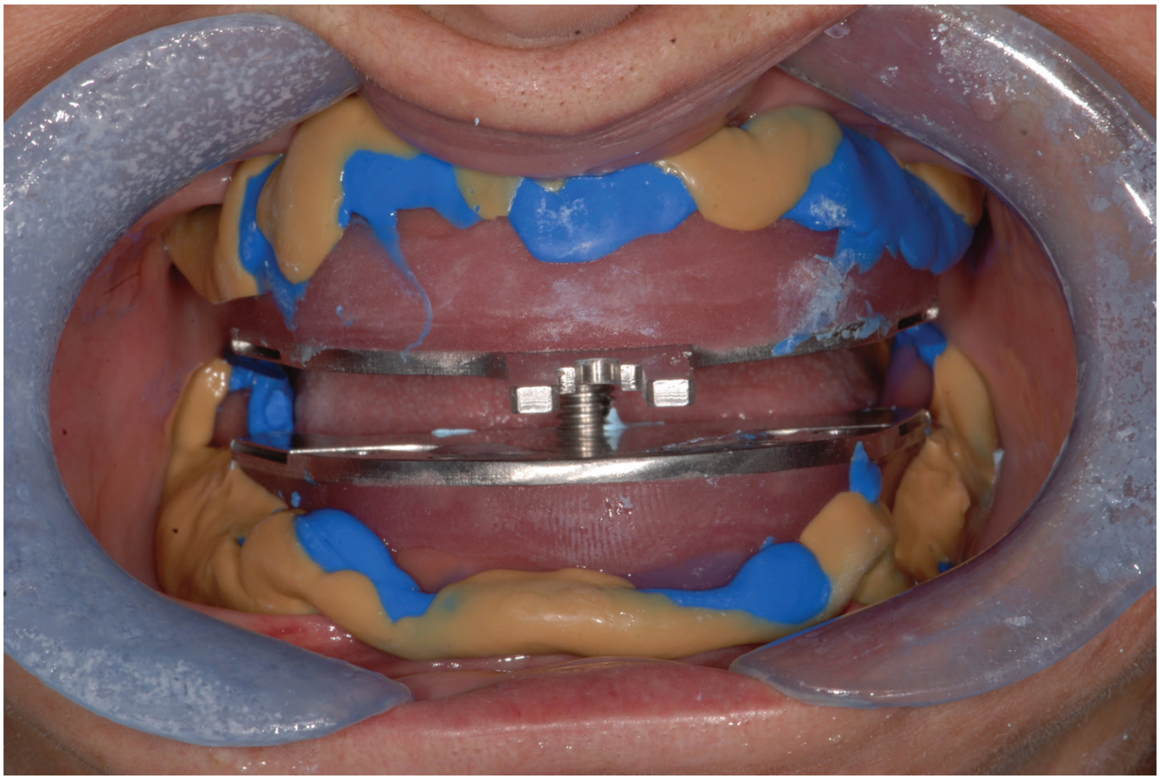

Figure 10. Central bearing point technique applied on edentulous patient.

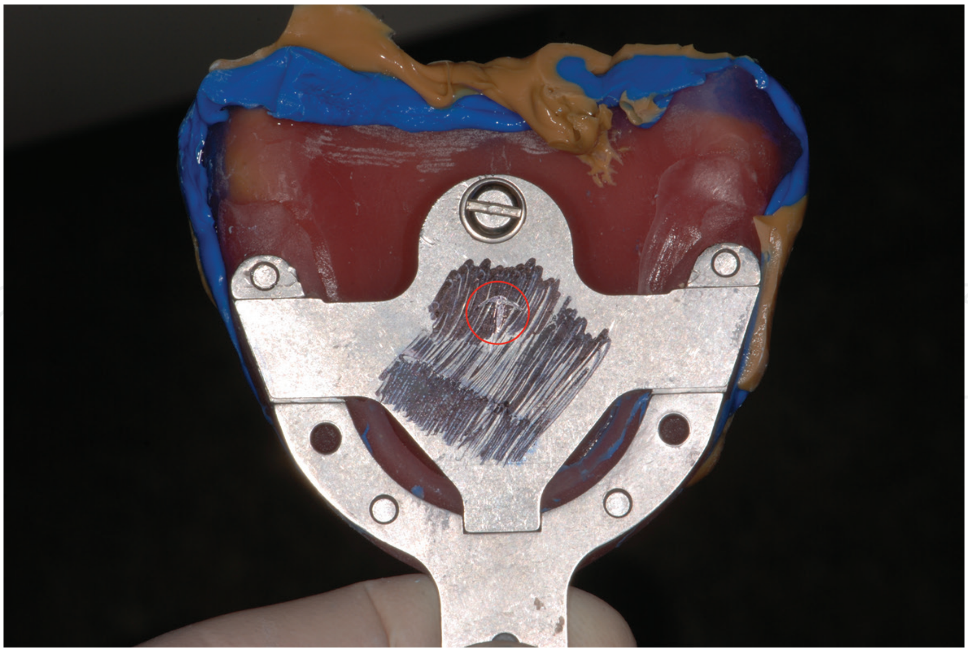

Figure 11. Gothic arch tracing.

In restoring a single tooth or few teeth, the rest of occlusion is the best guide to design the occlusal anatomy and the restored tooth needs to be integrated in the existing occlusion, without introducing interferences in centric occlusion or eccentric movements. On the contrary, when extensive occlusal reconstructions are needed, reference points need to be derived from the structure other than residual occlusion. These reference points are the other component of the masticatory system that limits functional movements. In particular, the TMJ anatomy influences mandibular dynamics. Changes in occlusion made regardless of TMJ anatomy may introduce occlusal interferences during movements. For these reasons, it is fundamental to record some particular parameters to which the occlusion morphology is conformed. The most important (and the most used) parameters are as follows (a) the protrusive condyle path and (b) the immediate mandibular lateral translation (also known as immediate side shift), which influence both anterior guidance and dimension of the posterior cusps in the protrusive and lateral movements, respectively.

2.5. Which instruments are needed?

In an extensive occlusal restoration, it is necessary to work on patient's master casts that are mounted on an **articulator** that best reproduces hinge axis. In such a way, we can be reasonably sure that each occlusal change made on articulator will result in the same occlusal change on the patient's mouth. In order to do that, it is necessary to use a **face bow**, a calliper-like instrument that records the spatial relationship of the maxillary (or mandibular) arch to some anatomic reference point or points and then transfer this relationship to the articulator [22].

There are different types of articulator; the most frequently used are the **semi-adjustable** ones that represent an optimal compromise between the non-adjustable articulators, inevitably inaccurate because they cannot be combined to a face bow, and fully adjustable articulators, more precise but also more complex to use. If you are well aware of those that are the principles that must be applied, you can equally get a good result even using a less complex and precise tool.

After recording the hinge axis, the two parameters that are usually recorded are as follows:

a. The protrusive condylar path. The functional part is represented by the intermediate segment, used to calculate the angle to be set in the articulator,

b. The immediate side shift on the horizontal plane that is the movement of the not working condyle that guides the lateral movement.

These two parameters are dependent on the anatomy of the glenoid fossa and influence the anterior guidance and the occlusal morphology of the cusps of the posterior teeth during eccentric movements.

2.6. Which restorative materials are used?

The ability of some dental materials to adhere to dental tissues has dramatically changed the modern dentistry, modifying operative protocols, techniques and even treatment plans. 'New' glass-ceramics like lithium disilicate combine good mechanical properties with excellent aesthetic results. The strong point of this ceramics is adhesive cementation on the tooth, a property that stronger polycrystalline ceramics like zirconia are lacking of. Indeed, the surface of lithium disilicate may be etched by hydrofluoric acid that dissolves the glass matrix to increase surface energy and, consequently, bond strength to dental tissues. Such a surface treatment is impossible on zirconia because no glass matrix is present. The clinical consequence is the use of lithium disilicate for producing indirect restorations with no mechanical retention and resistance form. An *in vitro* study [27] was conducted to compare the retention of lithium disilicate crowns cemented using two different cementation systems: (a) a glass-ionomer cement (GIC) and (b) a self-curing luting composite resin. Adhesive cementation with luting composite showed failure load three times higher than conventional cementation with GIC. Furthermore, crowns cemented with luting composite most often failed by fracture; otherwise, crowns cemented with glass-ionomer cement most often failed by decementation. These results suggest a completely different biomechanical behaviour between the two luting procedures; the ceramic crown is etched and cemented by a luting composite resin cement become part of the tooth. The new system crown-cement-tooth has a resistance equal to the inner tensile strength of an intact tooth.

The interface between tooth, luting composite and lithium disilicate surface was qualitatively evaluated using a scanning electron microscope (SEM). SEM analysis showed the three layers with no interruptions (**Figure 12**); by increasing the enlargement the interface did not change [28].

An *in vitro* study was conducted to compare the fracture resistance of human teeth restored with lithium disilicate only restorations, with and without a retention and resistance form.

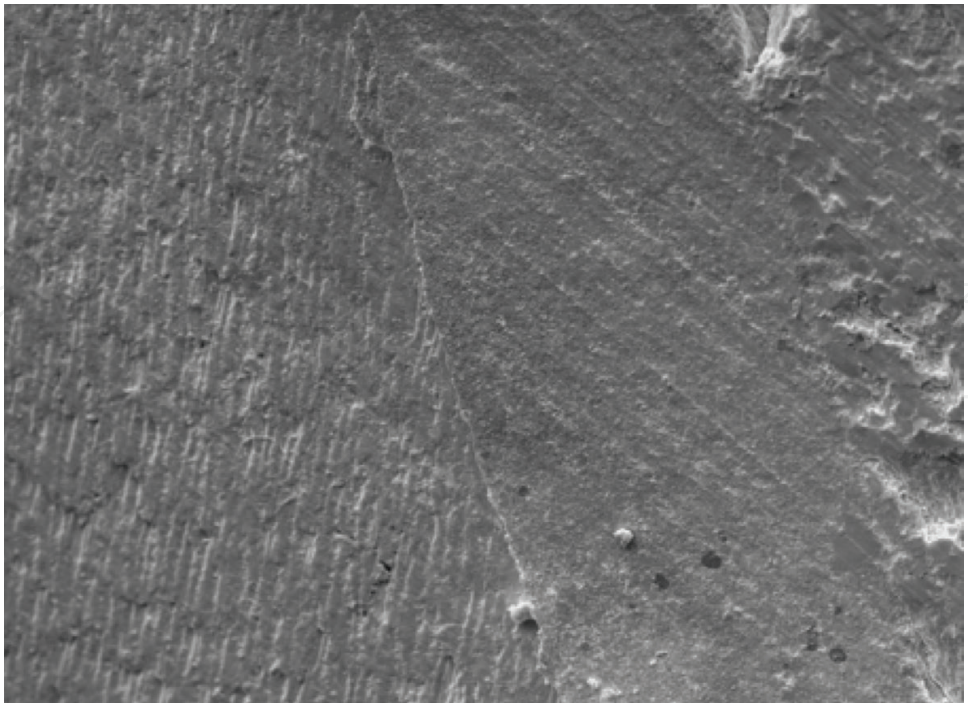

Figure 12. SEM evaluation (800×) of the (from left to right) tooth-luting composite-ceramic interface.

The fracture test (**Figure 13**) showed no difference between the groups, revealing that if adequate adhesive procedures (using etching ceramic like lithium disilicate) are applied, traditional concepts of tooth preparation (retention form, resistance form, ferrule effect) are no longer required for the mechanical resistance of restored teeth.

Because of its capacity to adhere to dental tissues,lithium disilicate.may be used to restore the lost anatomical and functional form of the teeth. This property is combined with excellent optical properties and very good mechanical properties that make this material the first choice to restore single anterior and posterior teeth, with total or partial restorations. It may also be used for realizing anterior 3-unit bridges. Even if its use for implant prosthesis is not generally recommended, a screw-retained implant crown realized by lithium disilicate has recently been described [29]. For higher load-bearing situation, like long-span bridges or complete arch rehabilitation, other materials, like polycrystalline ceramics or traditional porcelain-fused-on-metals (PFM) are suggested. However, no real adhesion to dental tissues can be achieved with these materials.

Some concerns in using ceramics for restoring teeth regard its impact on tooth wear. In fact, dental materials may be worn by enamel or they may cause aggressive wear of enamel [7]. Holding the other factors constant, variation in enamel wear rate is related to the coefficient of friction (which is a function of the material) and type of wear mechanism [7]. Ideally, a restoration should have wear resistance similar to that of enamel [30]. The average wear rate on occlusal contact areas is about 29 μ/ year for molars and about 15 μ/year for premolars [30]. The attrition of restoration is of clinical importance only if it deviates from the physiological attrition of enamel [31]. Too hard materials dramatically accelerate wear of antagonist enamel

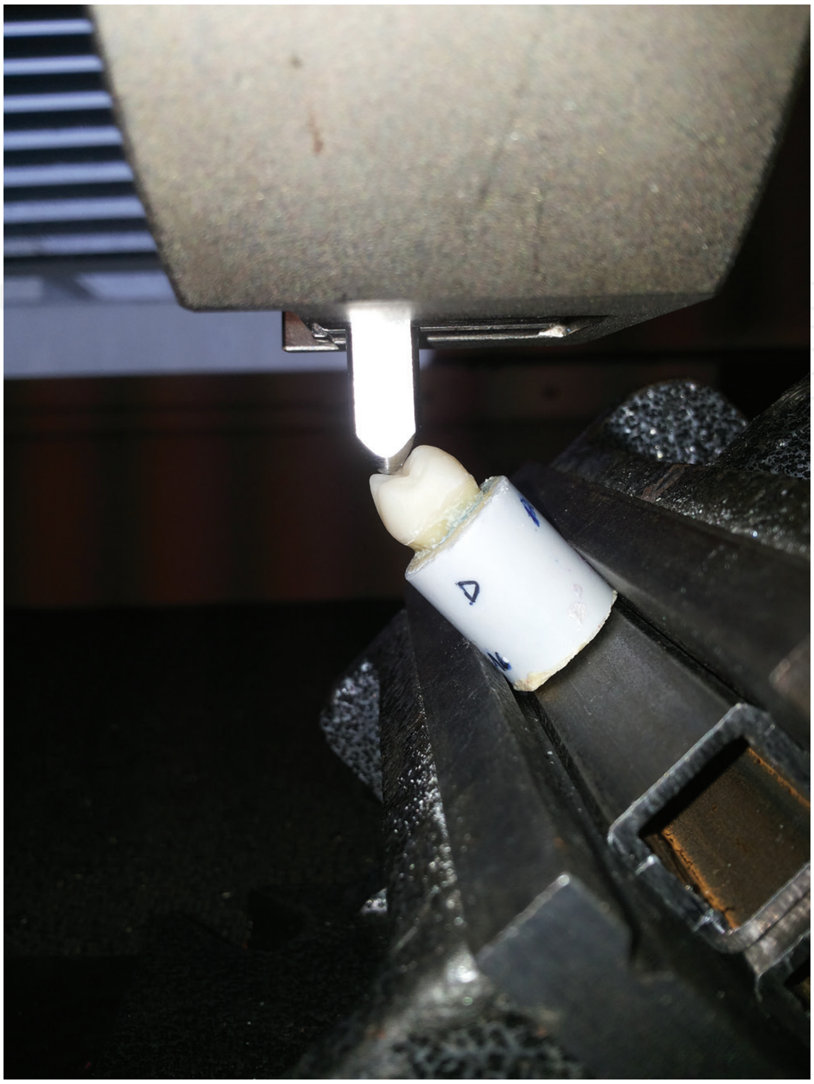

Figure 13. Fracture test of natural tooth restored with lithium disilicate restoration.

(**Figure 14**). For example, the enamel-ceramic combination wears more than the enamel-enamel combination and both wear more than enamel-amalgam combination [7].

Among the various dental materials, composite resins have a particular behaviour as many variables that derive from their composition directly influence their wear resistance. Composites consist of filler particles dispersed in a brittle polymer. The size, shape and hardness of the fillers, the quality of the bonding between the fillers and the polymer matrix and the extent of polymerization of the polymer matrix influence the wear characteristics of the composite. Furthermore, the composition of the material influences physical parameters such as flexural strength, fracture toughness, hardness, modulus of elasticity and curing depth, all of which may influence the wear [32].

In general, composite resins are susceptible to abrasive and fatigue wear [33]. The mean occlusal contact wear of composite materials ranges from 60 to 200 μm, depending on the material, attributing lower wear rates for composite resin launched in the mid-1990s compared

Figure 14. A ceramic crown on left upper central incisor, associated to deep bite, caused an augmented wear due to attrition of antagonist teeth.

to those that were launched at the end of the 1980s or beginning of the 1990s. However, the range of wear may vary considerably within the same material [34]. The latest composite resins, with smaller fillers, do not show excessive wear. Many variables related to the composition of composite resins influence wear resistance. Composite resins with small particles are more wear resistant than those with large particles [35, 36]; composites with more than 48% volume of fillers have a higher wear resistance [37] the filler inter-particle spacing of less than 0.10–0.43 μm is needed to protect the resin matrix from wear [37]. Experimental non-aged composites show similar wear regardless of the degree of conversion (DC) [37], and some commercial 7-days-aged composite resins with high DC show less wear than composites with lower DC [38]. There is some correlation between DC and hardness, but composite resins with high values for hardness do not necessarily have a high resistance to abrasive wear [39].

3. Conclusion

As dental clinician, we act every day on the occlusal interface. Being the masticatory system constituted by different components that influence each other, we must keep in mind that every change at one level will have consequences on the others. For this reason, altering or restoring the occlusion must consider the anatomical limits of muscles and joints, and the adaptive capacity of the nervous system. There are few basic principles that need to be fulfilled in occlusal rehabilitation, and an anatomical face bow and a semi-adjustable articulator represent useful tools to achieve the treatment goals.

The use of materials that can be adhesively fixed to dental tissues should be preferred. These include both glass-ceramics and composite resins. Ceramics present better mechanical and optical properties, but their high hardness may increase tooth wear due to attrition, especially when grinding habits are present. In these cases, the use of composite resin may be preferred.

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