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BIOMECHANIC LAWS APPLIED TO A FIXED DENTAL PROSTHESIS – HOW CAN THEY AFFECT THE REHABILITATION? A CLINICAL CASE

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ABSTRACT

The aim of this study was to discuss different oral rehabilitation options in terms of biomechanics when an abutment of fixed dental prosthesis is compromised. We present an alternative solution avoiding the placement of dental implants. Biomechanics principles of tooth-supported bridges were discussed and respected.

Keywords: Biomechanics, Ante`s law, fixed prosthesis, oral rehabilitation, beam, span.

INTRODUCTION

A fixed dental prosthesis (FDP) is any dental prosthesis that is retained to natural teeth, tooth roots, and/or dental implant abutments that provide a primary support for the dental prosthesis (The glossary of prosthodontics terms, 2005). It should be designed to have a long functional life (Mezzomo, 2006; Shilingburg, 1997).

When a tooth is lost it breaks down the structural integrity of the entire dental arch, with the consequent realignment of the teeth in a new equilibrium state. The edentulous space is often invaded by adjacent or opponents teeth (Mezzomo, 2006; Shilingburg, 1997). A tooth-supported fixed dental prosthesis is dependent on the characteristics and position of the remaining teeth, which must be evaluated in order to be prepared and used as rehabilitation abutments. The tooth that serves for insertion and support of this kind of prosthesis is called abutment, while the artificial tooth suspended between the abutments is called pontic (Shilingburg, 1997).

Tooth evaluation includes clinical and mechanical features. Clinically it should be analysed the relationship crown:root, root configuration and area of periodontal ligament, e.g. (Shilingburg, 1997). Mechanically, the stress behaviour should be examined according to number and position of the abutments, shape and design of the prosthetic structure and also to the material's ability to undergo and withstand stress (Malquarti, 1992).

Bridges should follow some principles: mechanical analysis of the beam or span, bending of the span, geometry and preparation of the abutments (Malquarti, 1992). Abutments must be prepared in order to be parallel, to create retention (Allard, 1992) and to have enough structure to support the loads carried out in the fixed dental prosthesis. The loss of mineralized structure is the main factor of fragility and fracture of a tooth. Intact teeth have more ability to withstand occlusal loads, unfortunately patients with the need of rehabilitation normally have different clinical conditions (Mezzomo, 2006; Rosenstiel, 2006). When there is doubt about the integrity of a tooth it is preferable to extract and think on an alternative rehabilitation solution (Mezzomo, 2006; Rosenstiel, 2006). The pontic length is dependent on the abutments and their ability to accept extra load. Bridge biomechanical principles are based in the following laws: (Malquarti, 1992).

- Béliard Law - The increased number of non-aligned abutments improves the conditions of equilibrium, limiting the number of axes of rotation (Malquarti, 1992).
- Sardin Law - The pronounced curvature determines an overturning moment that must be balanced using an additional support (Malquarti, 1992).
- Duchange Law - Using the coronal morphology of the occlusal surface and occlusal position in the arch, an intrinsic coefficient is assigned to each tooth. The sum of the coefficients of abutment teeth must be greater or equal to the sum of the coefficients of missing teeth (Malquarti, 1992).
- Ante's law - The root area of the abutments must be equal or superior that of the teeth being replaced by pontics (Mezzomo, 2006; Rosenstiel 2006; Shilingburg, 1997).
- Law of beams - The deflexion of a beam is directly proportional to the square of a load and to the cube of its length. It is inversely proportional to the cube of its height, to the cube of its elastic modulus and to its volume (Mezzomo, 2006; Raigrodski, 2002; Shillingburg 1997).

Complex fixed prosthodontic treatments need to be simulated and studied in articulated diagnostic casts (Rosenstiel, 2006). Short and straight edentulous areas to rehabilitate, using intact and correctly selected abutments with good bone support, have better predictability and prognosis. On long and multiple spaces the prognosis is more restricted but still viable (Mezzomo, 2006). In a general conception, Tylman stated that two abutments could support two pontics, being risky using more pontics (Shilingburg, 1997). Meanwhile, Mezzomo states that in exceptional cases three posterior pontics can be used, especially if it is located on the maxillary arch (Mezzomo, 2006). Moreover Rosenstiel states that replacing three posterior teeth with a FDP rarely has a favourable prognosis, especially if is located on the mandibular arch (Rosenstiel, 2006). Developed loads will require greater resistance of its components so that there is no loss of retention, infiltration and subsequent caries. Incorporating secondary abutments can increase the area of contact, leading to a better distribution of the loads (Mezzomo, 2006). Some cases are compromised and alternative treatment plans must be considered in terms of biomechanics.

OBJECTIVES

The aim of this study was to present and discuss different oral rehabilitation options of a borderline clinical case in a biomechanical point of view.

CLINICAL CASE

A 66-year-old female presented wear of anterior teeth and the absence of upper premolars (14, 15, 24, 25), lower second premolars (35 and 45) and lower molars (36, 37, 46, 47), as it is shown in Fig.1 and Fig.2.

Fig.1 Initial intra-oral photographs: lateral and frontal views

Fig.2 Initial Orthopantomography

After diagnosis, evaluation and discussion, the treatment plan chosen was a maxillary full-arch fixed prosthesis and a mandibular removable prosthesis (Kennedy class I). The patient did not present any parafunctional activity. All remaining upper teeth, with no mobility and few bone loss (normal for the patient age), were used as abutments (from 13 to 23, 16, 26 and 27); there was a length of 19mm, between 16 and 13, and a length of 16mm between 26 and 23. As the treatment went along, it was required to perform an endodontic treatment on one abutment (tooth 26) that failed due to technical reasons. At first, hemisection was made, but the abutment was too small, impaired and could not help bridge support. To overcome this issue, we decided to extract the tooth. The initial treatment plan maintained practically the same. The final result is shown in Fig.3 and Fig.4.

Fig.3 Final intra-oral photographs: lateral and frontal views

Fig. 4 Final Orthopantomography

DISCUSSION

The main goal of oral rehabilitation is to reach a total mechanical and biological equilibrium (Mezzomo, 2006). When a treatment plan is executed, sometimes we have to adapt due to complications. Even clinically evaluating the crown:root relationship, root configuration and area of periodontal ligament of tooth 26 as good at the beginning of the treatment, other factors were crucial. An amalgam restoration close to the pulp, the tooth anatomy, a mesial inclination and the need of parallel abutments leaded to endodontic treatment. Many articles presented in dental literature suggest that the success rate of endodontic treatments can be in the order of 92% to 98% (Dawson, 2006). Unfortunately the attempt to do an endodontic treatment leaded to a failure, letting three options: preservation, hemisection or extraction of tooth 26. Despite all efforts, the access to buccal canals was compromised not allowing an adequate endodontic treatment, so preservation of tooth was discouraged. Hemisection could be an option, but the integrity of the palatal root was affected and the periodontal support was deficit.

The teeth used as abutments support forces greater than those supported by intact teeth (Mezzomo, 2006). Tooth extraction would be the most suitable option since the long-term survival of this tooth can be doubtful. Nevertheless, this option involved the extension of the prosthesis's span or the placement of implants.

With implants there were two main options: a) segmentation of the rehabilitation: placing two implants (24 and 26), one implant-supported fixed bridge of three elements (24, 25, 26), a tooth crown on 27 and a conventional fixed tooth prosthesis 16-23; b) maintaining the total rehabilitation: putting an implant on the position of 26 and transforming the totally tooth-supported on a tooth-implant-supported fixed rehabilitation. Implant placement may have contraindications and the success depends, among many factors, on the quality and quantity of bone available. The second implant option would involve a controversy subject mixing two different biomechanical systems. As many women in postmenopause period, the patient was undergoing osteoporosis treatment and has been taking bisphosphonates for more than five years. Due to the high risk of bisphosphonate-related osteonecrosis of the jaw, implant treatment was not an option.

Without implant option we reanalysed the situation. Parafunctional activity or chronic bruxism, even with a well-balanced occlusion, would present a higher risk (Mezzomo, 2006), but on this case it was not detected. Since a posterior abutment was present (tooth 27) and the lower opponents were acrylic teeth of a removable rehabilitation, an extension of the prosthesis's span was chosen. This would implicate with biomechanical aspects.

Articulated diagnostic cast was waxed to simulate and study this option. There was practically a correct occlusal plane and a correct vertical dimension. Otherwise, if there was a presence of an irregular occlusal plane or an undesired vertical dimension that needed to be corrected, implant supported or removable prosthesis would be recommended (Rosenstiel, 2006)

Initially on this upper side, there were two missing teeth with a length of 16mm and a favourable relative root area with the primary abutments (23 and 26), considering Ante's Law. After the loss of the tooth 26 there was one more missing tooth and a new length of 23mm, which leaded this clinical situation to be unfavourable regarding Ante Law, so the design of the fixed dental prosthesis had to be changed. The Fig.5 represents the analysis of both spans. The sum of the relative root area of the three missing teeth was 887mm^2, primary abutments presented an area of 704mm^2 which was lesser than the first one, so secondary abutments were needed. The tooth 22 has a small relative root area of 179mm^2, which was less than it was needed; the tooth 21 has a relative root area of 204mm^2. Using both teeth 22 and 21 has secondary abutments, with a total root area of 383mm^2, and adding this area to the primary abutments, it was possible to reach a total of 1087mm^2, which exceeded the root area of the missing teeth. Planning a splinted full-arch prosthesis the abutments on the other side were used and gained. This splinted rehabilitation, with two spans involving five missing teeth with a total relative root area of 1341mm^2, supported on eight abutments with a total relative root area of 2176mm^2. The intrinsic coefficient assigned to each tooth is proportional to its relative root area, so Duchange Law was also applied. Achieving a more favourable situation in terms of Ante and Duchange Laws other features were still rethought. A secondary posterior abutment would be also desirable in terms of equilibrium but on this case it was not an option, so the preparation of the tooth 27 was modified. Multiple grooves, including some on the buccal and lingual surfaces can be preformed in order to produce greater resistance and structural durability (Mezzomo, 2006; Shilingburg, 1997). On this case, involving upper teeth, a lingual groove was done.

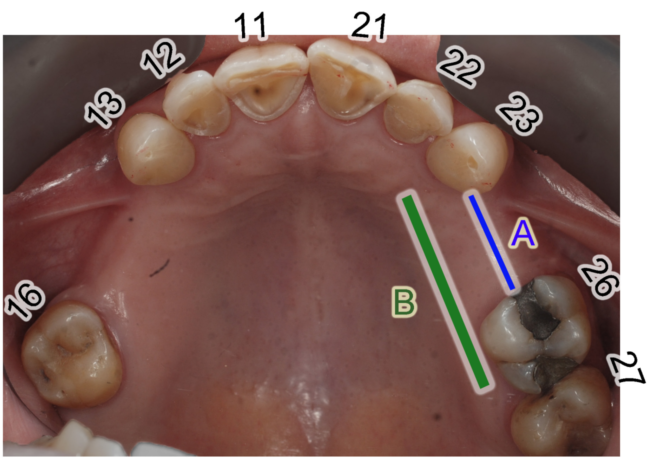

Fig. 5 Upper Arch Analysis

A – Initial span length
B – Final span length

It would be simplistic to attribute the failure of a bridge only to excessive tension on the periodontal ligament. Besides overloading the periodontal ligament, a long prosthesis will be less rigid. The destruction caused by stress has been attributed to the lever arm and twisting forces, and not to overload (Shilingburg, 1997). When the pontic suffers deflexion, tensile forces will focus on secondary retainers, which must have at least a similar root area to the primary abutment (Mezzomo, 2006; Shilingburg, 1997). Long spans have the potential to produce more twisting forces, particularly on weak abutments. Incorporating secondary abutments increases the area to absorb loads. Planning a splinted full-arch fixed prosthesis, where all the remaining maxillary teeth are used as abutments, the conditions of equilibrium improved, limiting the number of axes of rotation, following Beliard's Law.

The bending or deflexion of a span is directly proportional to the cube of its length and inversely proportional to the cube of its height (occlusogengival thickness) (Shillingburg, 1997). Deflexion has its greater value when forces are applied on the centre of a span (Mezzomo, 2006). Under a given force, a pontic with an occlusogengival dimension undergo a deflexion eight times greater if its thickness is halved. In order to reduce flexure caused by long or narrow spans, the occlusogengival size must be increased (Shillingburg, 1997), especially on the connectors to the pontics (interproximal space), which are the most fragile (Mezzomo, 2006). When a long span is fabricated, pontics and connectors should be made as bulky as possible to ensure optimum rigidity without jeopardizing gingival health (Rosenstiel, 2006). A posterior prosthesis is mainly subjected to axial/vertical forces, so an augmentation on this way (higher than wide structure) will create greater resistance (Mezzomo, 2006). The minimal recommended dimensions for a metal-ceramic connector are 2.5mm height and 2.5mm width (Raigrodski, 2002). On this rehabilitation the distance between the abutments increased, still occlusogengival space was high, so a higher bridge design was done, placing pontics connector structure as thick as possible (infrastructure dimension: height=3mm; width=4mm), ensuing the Law of Beams and a healthy gingiva. Occlusal contacts were reviewed in order to not apply too much force on the middle of the span. The affected area did not have a pronounced curvature, not applying Sadrin's law.

The metal-ceramic bridges are used when a good aesthetics and a highly resistantance to fracture is needed. The metal-ceramic bridges have a very satisfactory union of the materials. It is essential that this union (mechanical compressive forces, Van der Waals forces and chemical bonding) be performed on a rigid infrastructure with suitable design for the ceramic support. Also the ceramic and the metal alloy have to be compatible.

Although some ceramic systems already allow, under favourable occlusal conditions, rehabilitation of three or more elements without using metallic frameworks, the use of an all-ceramic bridge must be well balanced (Raigrodski, 2002).

Mechanically, beside of stress distribution (according to the number of abutments, shape and design of the structure of the prosthesis) the material must have a good ability to suffer and endure the stress induced (Malquarti, 1992). Bridges are not totally rigid, the materials involved bend when required, according to their physical characteristics. This bend should not lead to fatigue or fracture and it is dependent on their rigidity (elastic modulus, form and volume). Regarding a dental fixed prosthesis, there is a necessity for the infrastructure to be rigid so it can avoid an exaggerated deflexion that may lead to loose or fracture. A higher elastic modulus will lead to a more rigid structure (Mezzomo, 2006).

Basic metal alloys have an elastic modulus around 200GPa and have advantage on rehabilitations of extended edentulous spaces (Mezzomo, 2006). In this case, we chose a cobalt-chromium (Co-Cr) metallic alloy to be used as infrastructure. This material containing

53-65% of cobalt and 27-32% of chromium has one of the highest modulus of elasticity (around 207GPa). It has a density of 8g/cm^3, tensile strength of 552-1034MPa, yield strength of 221-779MPa, hardness of 300, and an elongation of 2-3%. High stiffness coupled with relatively high yield strength suggests its usefulness on fabricating a conventional long span fixed prosthesis (O'Brien, 2002).

In our days, most of the solutions have their range and limit defined and no procedure will fully restore the absent natural teeth. Patients should be aware about their need to learn not only the benefits of their rehabilitation, but also the limitations (Mezzomo, 2006).

CONCLUSION

Most of the used principles are commonly used on engineering regarding the construction of bridges. The needed requirements of a span and abutments depend on the type, form, extension, dimension and force subjected (Mezzomo, 2006).

In order to maintain a fixed rehabilitation in the upper arch, the treatment plan presented can be a viable and secure option. Still, implants would create a more desirable situation and it would have been our first choice if they were possible. The presented alternative treatment has the advantages of keeping the same type of support, preserving practically the initial treatment plan, time and cost of treatment. The biomechanical analysis of this situation allowed us to proceed with the treatment of this complex case. Under this conditions metal-ceramic rehabilitation seems to be the most suitable to withstand masticatory loads, preserving the integrity and reliability of the materials involved.

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