Medial mandibular flexure related to biomechanical failures of implant-supported fixed prosthesis with rigid connection distal to the mental foramen

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Abstract

Introduction: Some mechanical failures and possible biological problems were related to the medial mandibular flexure in patients who had implant-supported fixed extensive prostheses, with bilateral rigid connection in implants posterior to the mental foramen. **Methods:** Literature research relative to the topic was performed from a query to the MEDLINE database, including papers published from 1954 to 2010. The purpose of this literature review was to compare the possible biomechanical failures of implant-supported prostheses with extension distal to the mental foramen, such as implant fracture, prosthesis screw loosening or fracture, lack of passive fitting of the metallic structure, bone saucerization, and in some cases, muscle pain and limited mouth opening, and to propose a design to these prostheses. **Conclusion:** When the prosthetic planning needs supporting elements at the surface posterior to the mental foramen, the prosthesis should be segmented, especially in the region of the symphyseal area. Thus, the deleterious effects of medial mandibular flexure in the prosthesis and peri-implant area will be minimized.

Keywords: Mandible. Dental prosthesis. Dental implants.

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Introduction

It was performed a literature review of the publications in which the medial mandibular flexure was related to implant-supported fixed prosthesis with rigid connection distal to the mental foramen, aiming at:

1) Suggesting the ideal biomechanics necessary for making this type of prosthesis.

2) Checking the care needed in the casting procedure.

The mandible is a single bone that with the muscle action is able to perform various complex movements. The medial mandibular flexure (MMF) is a deformation of the mandible resulting from these movements performed during normal physiological functions such as talking, chewing, etc. The muscle action during these movements makes both mandibular rami approach. In other words, there is a reduction of the intercondylar distance, mainly by the action of the lateral pterygoid muscle. These variations may be related to lateral pterygoid muscle synergy, the mandible elasticity and the mandibular fossae size of the temporal bone.[1]

The MMF has become an important aspect in dentistry, especially in the field of conventional and over implants prostheses. When the manufacturing of conventional fixed prosthesis has started, as a means of rehabilitating lost teeth, a lot had been studied on this topic, since there was a need, in many cases, to extend the metallic structure to regions distally to the mental foramen when the patient did not agree with the rehabilitation through removable dentures.[2,3]

There are several studies about the possible consequences of bilateral rigid connection with distal extension in conventional prostheses. Some associate MMF with muscle pain, limited mouth opening, absence of prostheses passivity, bone loss, fracture of prosthetic structures, among other complications.[4] With the onset of Implantology, the replacement of fixed dentures in mandible by implant-supported fixed prostheses became a reality and with it the demand to resolve the problem of medial mandibular flexure. So, this literature review aims to analyze the biomechanical aspects of this type of statement, as well as, to assist in proper planning for this type of case.[2,3]

Literature review

Researchers measured the relative movement and the transmission of forces between dental osseointegrated implants in premolar regions of edentulous mandible, by means of a transducer connected to the dental implants. These implants showed deformations up to 420 μm (= 0.42 mm) and a force transmission up to 16 N in mouth opening and 8 N in mouth closing. It was observed that the forces were much smaller in lateral excursions than in opening and protrusion, as a result of the mandible movement from the rest position. While the effects of these phenomena are not known, it was observed that they can be potentially harmful to the interfaces between implants and bone and to the various components of the implant superstructure. The authors of this study reported great variation among individuals and a greater tendency to displacement when the implants were much separated and installed in thin mandibles, especially in the symphysis region. They suggested that this condition can be present in some patterns of implant failure, such as prosthesis screw loosening.[5]

An extensive review of the literature illustrated by clinical cases described nine factors involved in the manufacture of implant-supported fixed prostheses that may promote deleterious effects, including the torsion and medial mandibular flexure. The author points out that the flexure and torsion occur in the mental foramen area, and their magnitudes increase at most distal points to it. The narrowing that occurs can be measured with calipers. It was concluded that the loss and/or fracture of components and damage to bone can occur by this factor, and for this reason, caution should be taken in choosing the alloy and the design of the prosthesis to be used.[1]

Authors, by means of an in vitro study, tested the hypothesis that medial mandibular flexure influences the distribution of forces in the mandible/implant/superstructure complex. Six Brånemark® implants were placed on a replica of a human edentulous mandible, manufactured with acrylic resin. The applied forces were measured with four resistance extensometer elements mounted on each of the six pillars of standard titanium. The mandible was upheld by its lower border and was suspended in a framework that simulated the natural situation. A gold alloy superstructure was mounted in various combinations with the implants and occlusal loads at different sites. The resulting forces from each transmucosal abutment were measured. The suspended position ("natural") was associated with significant differences in patterns of force transmission in comparison with the replica of the mandible supported on the workbench. The loads were the most widespread, and large extrusion forces were detected, especially when multiple implants remained connected. The MMF is an important factor in the manufacture of dentures supported by implants in the mandible, and casts doubt on the value of impression-taking techniques that do not allow this phenomenon. The clinical implications are that MMF had a significant influence on the force distribution in the implant-host complex, and can increase the tensile forces in abutments supporting the fixed superstructure.[6]

It was analyzed 317 cases of tripodial subperiosteal implants in symphyseal regions and in mandibular angle. It was found that there was no flexibility in the middle portion of the mesostructure, the medial mandibular flexure rate would be greater than at the posterior portion of the implant and the patient could experience pain when performing wide mouth opening. The correction of the problem was made by cutting the middle portion of the mesostructure in the symphysis area thus enabling the medial implant flexure at a level compatible with the mandible, so the patient had immediate relief of symptoms. The flaws with this type of implant were attributed mainly to a mismatch between the posterior medial mandibular flexure and the rigidity of the metallic alloy used.[7]

Authors report an average approximation of 2 to 4 mm of the mandibular condyles and this value varies according to the bone quality, age, sex, and musculature of the patient. Approximately 2% of patients present movements bigger than 4 mm. This yields an approximation of 250 to 1000 micrometers (0.25 to 1 mm) in the gonial angle and 100 to 400 micrometers (0.1 to 0.4 mm) in the first premolar in which movements of mandibular ramus and body have been combined. This has a major influence on the treatment plan of patients being rehabilitated with tripodial subperiosteal implants.[8]

In a study of 30 patients, the author developed an apparatus to measure mandibular flexure, with the oral cavity opened and closed, which was attached to dental implants. The author believes that, due to the lack of Sharpey's fibers, implants transmit entirety to the bone, the medial mandibular flexure. It was found MMF exceeding 1 mm in 10% of patients.[9]

It was conducted a study to measure the mesial convergence, corporal rotation and dorsoventral shear in human mandibles. Measurements were performed using custom manufactured displacement transducers in six edentulous subjects who had been treated with dental implants in the mandible. These were mounted on the most distal mandibular implants on each side, and measurements were made in real time using an Analog/Digital multichannel converter and a personal computer for data storage and analysis. Measurements were made while the implants were loaded, and the patients performed lateral excursions of the mandible, opening and closing the mouth. The medial convergence was measured as a linear variation in the most distal implant site. The dorsoventral shear was expressed as a relative rotation of the right and left mandibular bodies projected in the median sagittal plane. The corporal rotation was expressed as the relative rotation of the most distal implant. The medial mandibular flexure occurred immediately after mouth opening and was related to the mouth closing and mandibular protrusion forces. Medial convergence of up to 41 µm (0.04 mm) was observed, with corporal rotation values of up to 6° and dorsoventral shear up to 19°. This study clinically demonstrated, for the first time, three different and concurrent patterns involved in functional medial mandibular flexure, namely: Medial convergence, corporal rotation and dorsoventral shear.[10]

Authors reported a possible correlation between the MMF and discomfort experienced by a patient rehabilitated with full-arch implant-supported fixed protheses. The patient discomfort was reduced after sectioning of the prosthesis into three parts. An prior attempt was made to section only its midline, which partially alleviated the symptoms. The authors concluded that symptoms occurred only in the opening and protrusion; at rest and laterality, there was no pain.[11]

Researchers reported that when an edentulous mandible is rehabilitated with four or more implants united by a screwed metal bar, MMF can cause loosening of the screws and unnecessary stress and deformations on the prosthesis and implants. The authors describe a clinical case with a bilateral rigid connection prosthesis with distal extension presenting undesirable consequences of MMF and conclude that separating the prosthesis in the midline can alleviate these stresses and deformations.[12]

Authors conducted a study to elucidate the effect of the installation of additional implants in the posterior region of the mandible for treating edentulous patients. Fifteen edentulous patients who received implants (Branemark System®, Nobel Biocare, Göteborg, Sweden) were selected and completed one-year follow-up after the installation of fixed prostheses. In seven patients (Group A), four or five implants were placed between mental foramina; and in other eight patients (Group P), one or two implants were installed on each side of the posterior region, in addition to the implants between the foramina. All implants in both groups achieved osseointegration. In Group A, there was no implant loss after loading. However six implants were lost in five patients in Group P within a year after loading. All lost implants were located in the posterior region. To elucidate whether the failure rate of implants in the posterior region of the Group P after loading was particularly high, the failures were also compared with 89 implants which were installed in the posterior region of the mandible to support partial fixed prosthesis during the same period (Group C). The cumulative survival rate for the implants on the Group P was of 60%, while for the Group C implants was of 100%. The MMF, due to mandible movement, was identified as the most likely cause of implants loss.[13]

Researchers discussed the biomechanical effects of medial mandibular flexure in the accumulation of stress in implant-supported fixed restorations. Relative deformations and stress distribution were analyzed in six models of different implant-supported prostheses systems (six or four implants, with or without distal extenders, full-arch or bars dividing it into two independent prostheses) by means of a three-dimensional finite element model of a human edentulous mandible. A significant amount of stress on the most distal implants and lifting of the superstructure in the region of the symphysis arise as a consequence of the medial mandibular flexure.

The analysis of the generated stress distribution by different restorative patterns suggest that a division of the superstructure at the symphysis level significantly restores mandibular natural functional flexure.[14]

An in vitro study was conducted to determine the influence of splinting implants on stress distribution in two different bone-implant experimental models. Models simulated the placement of four implants in the region between foramina and two additional implants in the mental post-foramen region. The stress distribution in each implant was evaluated by applying a static load on the superstructure. Three types of structures were studied: 1) metallic structure supported by all six implants, 2) structure in resin, and 3) metallic structure supported by the four anterior implants and tapered abutments removed from posterior implants. In all types of superstructure, stress was observed in all implants, with a greater magnitude in the posterior implants on full-arches when compared to anterior ones. This stress can be regarded as the cause of failure of a large number of posterior implants, and the authors believe that this stress is caused, in part, by the MMF that would lead to marginal bone loss in implants.[15]

Regarding prosthetic considerations on implant-supported prostheses, a author reported that to compensate the medial mandibular flexure caused by the pterygoid muscle contraction, the prosthesis can be constructed in segments; thus it does not have a rigid structure involving functional bone flexure, which could generate stress and potentially lead to loss of osseointegration and then to failure. The author, in the same year, described a clinical case using these principles.[16]

Through a literature review of *in vivo* studies, it was shown that in the MMF when force opening the mandible, there is a decrease in mandible width. The average amount of U-shaped flexure was 0.1160 mm, and in V-shaped flexure was 0.1864 mm. There was no significant difference in the degree of flexure between gender, selected age and different configurations of the mandibular arch. A minimal mouth opening was observed as ideal for prostheses molding.[17]

It was studied the MMF which is manifested in the midline during nonmasticatory functional movements in edentulous individuals rehabilitated with bilateral dental implants. The authors assembled displacement transducers on implants located in the anterior region, near the midline and measured three movements: Medial convergence, corporal rotation and anteroposterior shear. As results, values from 15 to 42 µm (0.01 to 0.04 mm) were obtained in opening, from 10 to 21 µm (0.01 to 0.02 mm) in laterality and from 18 to 53 µm (0.02 to 0.05 mm) in protrusion, for medial convergence; for corporal rotation values ranged from 0.05 to 0.11 degrees in opening, from 0.03 to 0.08 degrees in laterality and from 0.03 to 0.15 degrees in protrusion; anteroposterior shear ranged from 38 to 93 µm (0.04 to 0.09 mm) in opening, from 28 to 56 µm (0.03 to 0.05 mm) in laterality and from 52 to 103 µm (0.05 to 0.1 mm) in protrusion. They concluded that it is important for the clinician to be aware to these deformations, taking them into account in the design and monitoring of prostheses.[18]

Researchers believe that MMF can affect the stress distribution in implant-supported fixed partial prostheses and, however, this factor has been neglected in most finite element analysis of the mandible. Thus, in order to investigate the effect of two different types of superstructure on the stress distribution in mandibular bone during the flexure caused by the closure, it was created three-dimensional finite element models consisting of mandibular bone, six implants, and of two- or three-piece superstructures. Muscle forces with defined direction and magnitude were exerted on the fixing areas to simulate the molar closure and the incisal closure, situations in which a significant amount of MMF occurs.

The analysis was carried out using von Mises stress values. During molar closure, the two-piece superstructures showed higher stress values. During incisal closure, the three-piece superstructures inhibited more flexure than the two-piece superstructures. The MMF was an important factor in the distribution of stresses in the models, and therefore it should be considered in the planning of implant-supported fixed partial prostheses in the mandible.[3]

Discussion

The mandible, for being part of the stomatognathic system, presents a dynamic of movement.[1] The contraction of muscles during mandibular movements place the mandibular condyles closer to each other, generating stress lines in the region of the chin.[3] Flexure and torsion occur mainly in the area of the mental foramen, and their magnitudes increase for the most distal points.[4] Through photographic comparisons, three different and concurrent patterns involved in functional medial mandibular flexure (medial convergence, corporal rotation and dorsoventral shear) were clinically demonstrated, a fact later confirmed by other authors.[2,16]

The flexure movement occurs not only in the opening and protrusion movement, it also occurs in laterality, retrusion and closing movements, but with less intensity.[6] Other authors also observed that the mandible performs flexure when it is taken to centric relation position, but in an direction opposite to the movement of opening and protrusion, i.e., there is an increase in the width of the dental arch.[9,18]

Among the factors that control the magnitude of this flexure it can be related the age, bone density and muscle strength of the individual, geometric factors of the mandible and face may also be associated.[7] The area of symphysis and the mandibular length are some of these geometric factors. Individuals with lower symphyseal and bone density and larger mandibles tend to have major changes in the width of the arch.[2] Other studies found no relationship between the symphysis dimensions and mandibular deformations, but their authors themselves reported that the number of studied patients was relatively small.[2,8]

According to some authors there is no significant difference in medial mandibular flexure in the maximum opening between men and women, age ranges and different configurations of the mandibular arch.[12,13]

Several authors have attempted to quantify the medial mandibular flexure, and found 0.07 mm for second molars region and 0.03 mm for first premolars region. Others presented mean lateral flexure values of 0.073 mm and mean flexure in mouth opening of 0,093 mm. Some authors showed deformations of up to 420 μm (0.42 mm) and a force transmission of up to 16 N, being 8 N in closing[4,8,9]. Authors reported a mandibular condyles mean approaching of 2 to 4 mm, also claiming that, in approximately 2% of patients this value is greater than 4 mm; as a result it occurs an approximation of 250 to 1000 μm (0.25 to 1 mm) in the gonial angle and 100 to 400 μm (0.1 to 0.4 mm) in the premolars. Other researchers point medial convergence values of up to 41 μm (0.04 mm), corporal rotation up to 6 degrees and dorsoventral shear up to 19 degrees.[10,11]

Due to the high level of medial mandibular flexure that occurs in the mouth opening, as reported in the literature, many authors suggest the castings to be manufacture with the mouth closed as much as possible, for the working models to have dimensions more coincident with MHI or CR. They also noted that if this factor is not respected, deleterious occlusal interferences will occur in the prostheses and consequently to the implant and the adjacent structures to it.[1,15,16]

The medial mandibular flexure may impair rehabilitation with partial removable prostheses, partial fixed prostheses and implant-supported prostheses. Among the potential clinical problems related in literature, it is cited the lack of passive adaptation of prostheses on their supporting elements, premature contacts and occlusal interferences, fatigue of structures and materials, and micro fractures in the cement film.[4,17,18] In natural teeth, the effects of MMF are compensated by the compressibility of the periodontal ligament, which does not happen in implant-supported prostheses.[1,2] In the case of implants, the problem due to this flexure would be the stress generated in the bone-implant interface and in the structure of the prostheses.[6] MMF has a significant influence on distribution of force on the bone-implant complex and also may increase the stress in posterior abutments which support fixed prostheses.[11] Excessive forces as occlusal overload, prostheses incorrectly designed and adjustment problems could cause osseointegration problems.[4] Additionally, certain systemic disorders, such as osteoporosis, may influence the pattern of mandibular flexure by altering bone mass. This could change the mechanics of patient-implant complex and lead to an overload on the bone-implant interface.[5] Forces generated by the medial flexure in mandibular movements could be involved in some failure patterns in Implantology, including screw loosening, mainly in patients with extremely distant implants and mandibles with reduced symphysis diameter.[11,16]

It is possible to exist a correlation between the medial mandibular flexure and symptoms such as pain and discomfort in patients using rigid implant-supported fixed prostheses.[7,15]

Analyzing the distribution of stresses generated by different restoration patterns it was suggested that a division of the superstructure at the symphysis level significantly restores the natural functional flexure of the mandible.[12,15,17]

Some authors have reported that sectioning the prosthesis in midline is not enough to completely relieve the stresses, since, in a clinical case presented, the division of the prosthesis in the midline only partially relieved the symptoms reported by the patient. They recommend segmenting the prosthesis in three parts, which was enough to eliminate pain presented by the patient in opening and protrusion.[4] Corroborating these findings some authors argued that during the closure of molars, the two-piece superstructures present higher stress values; on the other hand, during incisal closing, the 3-piece superstructures inhibit more the mandibular flexure than the two-piece superstructure.[3,13]

There is, to date, no conclusive evidence on the degree of MMF required to cause clinical problems. Also it is unknown the long-term clinical effect of it in oral rehabilitation. Despite the need for additional studies on the influence of the medial mandibular flexure in prosthetic treatment, it would be prudent to recommend the following procedures according to this literature review: impressions should be taken with the mouth as closed as possible, without protrusion and without application of muscle strength; evaluate the facial type, muscle strength and bone density before planning extensive or rigid bilateral dental prostheses, considering the possibility of not connecting the bilateral posterior segments in selected cases.[6]

Conclusion

Based on the present literature review, it was conclude that:

1. When the prosthetic planning for edentulous mandible allows the placement of supporting elements on the region posterior to mental foramen, the implant-supported fixed prosthesis should be segmented, especially in the mental symphysis region, thus minimizing the deleterious effects of medial mandibular flexure at the prosthesis, the implant and the peri-implant region.

1. Another decisive aspect is the functional impression, which should be performed with the mouth closed as much as possible without protrusion, in an attempt to reduce at the maximum the distortion of the working model and the subsequent prosthesis.

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