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Review

Clinical importance of median mandibular flexure in oral rehabilitation: a review

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SUMMARY The mandible has a property to flex inwards around the mandibular symphysis with change in shape and decrease in mandibular arch width during opening and protrusion of the mandible. The mandibular deformation may range from a few micrometres to more than 1 mm. The movement occurs because of the contraction of lateral pterygoid muscles that pulls mandibular condyles medially and causes a sagittal movement of the posterior segments. This movement of mandible can have a profound influence on prognosis and treatment outcome for various restorative, endodontics, fixed, removable and implant-related prosthesis. The review unfolds the causes, importance and clinical implications of median mandibular flexure in oral rehabilitation. This review also highlights the appropriate preventive measures and techniques that should be adopted by clinicians to minimise the effect of flexural movement of the jaw during oral rehabilitation. This would not only help clinicians to achieve a good prosthesis with accurate fit and longevity but also maintain the health of the surrounding periodontal or periimplant gingival tissues and bone.

KEYWORDS: mandibular flexure, muscles of mastication, mandible, mandibular jaw movements, cross-arch prosthesis, implants

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Introduction

Median mandibular flexure (MMF) is the mandibular deformation characterised by the property of mandible to flex inward during opening and protrusion movements of the jaw with reduction in the width of mandibular arch. These movements occur in frontal plane of the mandible and are caused by contraction of lateral pterygoid muscles. The mandible flexes around the mandibular symphysis with medial pull on the mandibular condyles and sagittal movement of the posterior segments (1–5). The mandibular flexure occur during forced opening and protrusion of jaw with the amount of flexure being more for opening than protrusion.

The deformation of mandible during flexure is so minimal that it is often overlooked and considered to have no practical significance. However, this trivial amount of mandibular deformation has emerged as a significant factor that can influence the prognosis and treatment outcomes for various dental and implant-related procedures. MMF has influence on the various anatomic considerations, periodontal therapy, restorative or endodontic procedures and fixed, removable or implant-supported prosthesis. This review article highlights the causes, types and clinical significance of MMF in oral rehabilitation of dental patients (6–11). This review also highlights the appropriate preventive measures and techniques that should be adopted by clinicians to minimise the effect of flexural movement of the jaw during oral rehabilitation. This would help clinicians not only to achieve a good prosthesis with accurate fit and longevity but also to maintain the

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health of the surrounding periodontal or periimplant gingival tissues and bone. The search involved the use of PubMed, Medline and Cochrane databases to search for clinical trials, review papers, case studies and case reports on various aspects of mandibular flexure, ranging from 1954 to 2014.

Aetiology and mechanisms of mandibular flexure

Median mandibular flexure is a multifactorial phenomenon. The mandible changes its shape through the extended pressure caused by the contraction of various muscles and ligament attachments. The pull applied by these attached structures not only cause alteration of the shape of mandible with reduction in arch width but also affect the relative position of the teeth which are located on the mandibular arch (Fig. 1).

The most important factor causing mandibular deformation is the contraction of external or lateral pterygoids in a frontal plane during opening and protrusion of the mandible (12). A 'U-' or horse shoe-shaped mandible is considered as a curved beam that is subjected to bilateral and unilateral loading. The lateral pterygoid contraction pulls the condyle and condylar neck medially and produces bending torque in the mandible. According to Hylander, the bending force was exerted mainly by the medial component of force exerted by the obliquely arranged lateral pterygoid muscles (Figs 1 and 2) (5, 14). Hylander (1990) tested patterns of symphyseal bone torque by bonding strain gauges to the symphysis of an adult Macaca fascicularis and postulated that the functional contraction of the lateral pterygoid muscle caused high strain in the symphyseal region and the symphyseal bending occurred by adduction of the mandible during mouth opening (11, 13). Based on his work, four patterns of jaw deformation during mandibular flexure were postulated: (Figs 1 and 2).

1 *Symphyseal bending:* Associated with medial convergence or corporal approximation: this type of strain is associated with contraction of the lateral pterygoid muscle during jaw opening movements (Fig. 1) (14).
2 *Dorsoventral shear*: This produces a shear force in the sagittal plane. It is a result of the vertical components of muscle forces from the lateral pterygoid muscles and the reaction forces at the condyles. The magnitude of the shear force is dependent on the points of application. During symmetrical loading, the amount of shear force is equal on both sides of the mandible; however, during unilateral loading, the amount of deformation differs between the working and balancing sides (Fig. 2) (14).
3 *Corporal rotation*: Occurs during rotation of the body of the mandible, usually during the lower stroke of mastication. The resultant force causes narrowing of the dental arch (Figs 1 and 2) (14).
4 *Anteroposterior shear*: Occurs as a result of contraction of the lateral components of the jaw-elevating muscles. It occurs late in the power stroke, and the bending moment increases from the posterior to the anterior region (14).

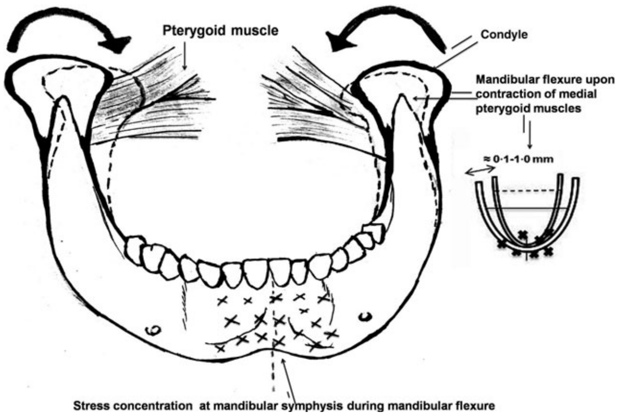

Fig. 1. Medial rotation of the mandible and decrease in arch width during mandibular flexure caused by contraction of lateral pterygoid muscle.

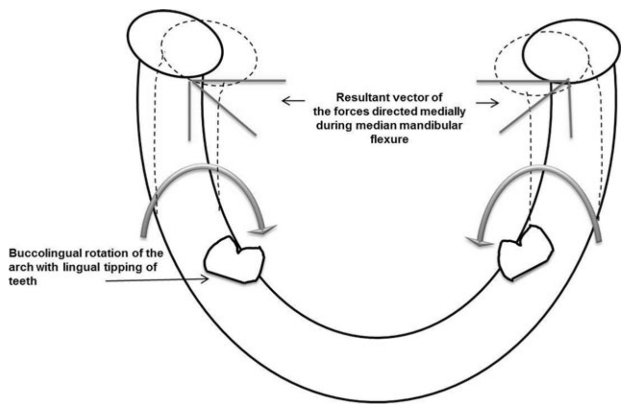

Fig. 2. Bucco-lingual tipping of the teeth in lower arch and stress concentration at mandibular symphysis area during mandibular flexure.

Apart from lateral pterygoid muscle, secondary assistance from the mylohyoid, platysma and superior constrictor muscles are also responsible for the medial movement of the condyle (12). The contractions of various depressor muscles of mandible also produce some change in the shape of the mandible. The muscles of the floor of mouth along with the two lateral pterygoid muscles exert a contracting force upon the mandible during opening and closing jaw movements. Mandibular flexure has also been observed during clenching, occlusion or biting forces on the mandible (5, 10, 12). Therefore, clenching that occurs in bruxism not only places an occlusal load but also causes mandibular flexure. This was confirmed by Omar and Wise, who reported that flexure of mandible not only occurred when occlusal load was placed on the mandible but was also present with muscular activity alone and during clenching. Their study measured mandibular flexure in a horizontal plane, when recordings were made with an 'anterior jig', chin-point guidance and patient-applied muscle force. Thus, it was concluded that the width of the mandible was influenced by both intrinsic and extrinsic forces and a horizontal retruding force on the mandible for centric relation records caused an increase in arch width (12). Moreover, the deformation of the mandible in the form of movement or shape is a complex phenomenon that involves interplay of many muscles of head and neck and may even occur without jaw movements (12, 15–19).

Thus, a stronger musculature is associated with larger mandibular flexure and variation in flexure due to varying degree of muscular development in an individual is considered normal. Because of the differences in muscular force for different facial patterns, brachyfacial subjects with higher muscular force compared with dolichofacial subjects demonstrate more flexure of the mandible during jaw movements (20–24). However, Shinkai *et al.* (2007) ruled out the significant effect of vertical facial pattern on MMF and did not support the hypothesis that maximum occlusal force and MMF vary as a function of vertical facial pattern. According to them, the functional outcome measures represented by muscular forces and mandibular flexure are the result of far more contributing factors than craniofacial morphology (23, 24). As lateral pterygoid muscle is relatively weak, the resistant bony structure may be much more dominant than the active muscle force for mandibular deformation during mouth opening (25, 26).

Thus, the physical properties of the mandible such as the shape or structural properties are as important as musculature to influence mandibular deformation. The symphyseal area and shape are some of the important factors that prevent symphyseal torsion and bending (14). Moreover, age, gender, bone density, musculature strength, symphyseal bone height and lower gonial angle significantly influence the amount of flexure (20). Subjects with larger mandibular length, lower gonial angle and smaller symphyseal area tend to have more mandibular deformation (19). *In vivo* studies have confirmed that the highest values of mandibular deformation occur in subjects with lower symphysis height (20, 21). Hobkirk *et al.* (1991) confirmed the influence of geometric facial factors on mandibular deformation using a lateral skull radiograph and proposed that the highest values of mandibular deformation occurred in subjects with lower symphysis height (21, 22). Although positive co-relationships between mandibular deformations and symphyseal width area exist, symphyseal bone density was negatively related to mandibular deformation (20). Therefore, in patients with osteoporosis or those with bone deformities, poor bone density tend to have increased mandibular flexure. Lower gonial angle that represents mandibular inclination also has a significant but weak correlation to mandibular deformation. The geometric factors of symphyseal width and area were closely related to mandibular deformation on mouth opening. Therefore, elder edentulous patients who tend to have smaller symphyseal areas and more porous skeletons are more prone to mandibular distortion during jaw movements (25–29).

The disparity between females and males has been observed with the dimensional changes in mandible being greater in females than males (23). Female subjects exhibit larger mandibular arch width change during flexure than males. According to Kemkes *et al.* (30), gonial aversion and mandibular ramus flexure could be an important morphologic indicator of sex. However, age and topical tooth loss may reduce the accuracy of these indicators to a greater extent. According to Balci *et al.* (31), the predictive accuracy of mandibular flexure for sex determination was more reliable in men than women. Further, Canabarro SA and Shinkai RSA in 2006 evaluated the association of

MMF with maximum occlusal force, gender, weight, height and body mass index and proved that subjects with high maximum occlusal force exhibit larger median mandibular flexure (19, 23).

The mandibular deformation may range from a few micrometres to more than 1 mm (2, 4, 9, 11, 19, 25). Different methods that have been used to evaluate and measure mandibular deformation include the following: intra-oral measuring techniques by callipers, gauges, strain gauges or transducers; extraoral measuring techniques by comparing diagnostic casts made from impressions taken at various openings of mandible and model simulations of three-dimensional finite element analysis (3–6, 11, 12, 32–34). McDowell and Regli (11) calculated the reduction between two mandibular halves during mouth opening as 0·4 mm and in protrusive movement to be 0·5 mm. While Burch and Borchers (1970) demonstrated a 0·61 mm decrease in the width of the mandible, Novak (1972) found the flexure to range between 0·3 and 1·0 mm (2, 36). Shinkai *et al.* (34) evaluated the intra- and inter-rater reliability of a digital image method for linear measurement of median mandibular flexure in dentate subjects and concluded that digital image method had excellent intrarater and good inter-rater reliability in identifying subjects with excessive medial mandibular flexure. Variation in mandible flexure is also noted during various jaw movements as follows:

1 *Opening and protrusion movements*: Regli and Kelly (1967) and Fischman (1976) demonstrated changes in mandibular arch width on diagnostic casts made from impressions taken at various stages of openings of the mandible and concluded that there were linear and rotational components of mandibular flexure (5, 7, 10, 11, 32, 34). Omar and Wise (12) had also shown a decrease in mandibular arch width in wide opening movement with a mean of 0·093 and a range of 0·012–0·164 mm. However, no change in the width of the mandible occurred up to 28% mouth opening and thereafter, the change in width was directly related to the extent of mouth opening (4).

2 *Right and left lateral movements:* According to Burch and Borchers (1970), the mandibular arch width decreases during movement from rest position to right and left lateral position. The mean magnitude of decrease in arch width was 0·243 mm in right lateral and 0·257 mm in left lateral (25).

3 C*entric relation position*: The recording of centric relation (C.R.), which is a valuable reference position for some prosthetic rehabilitation, is also associated with some amount of mandibular flexure (35–39). Omar and Wise (1981) compared the differences in mandibular flexure while recording C.R. in patient-applied muscle-force C.R. registrations and guided C.R. registrations using an anterior jig. The result showed an increase in mandibular arch width in guided C.R. registrations as compared to patient-applied muscle-force C.R. registrations. This proved that the mandibular flexure was more when centric relationships are recorded by patient-guided muscular movements (12, 35–38).

4 *Rotational movements:* The rotational movements are present during the opening cycle of the mandible with most of linear and rotational movement occurring during forced wide opening (1–7, 10–12). During this rotational movement of the mandible, the teeth will be recorded in a more lingual position along with a lingual rotation. This would change the bucco-lingual angulation of the mandibular teeth and cause several laboratory errors (Fig. 2) (3).

5 *External forces*: The mandibular arch width can be decreased by external forces, such as forces applied to resist jaw opening, and digital force directed medially and bilaterally to the condyles (24).

Clinical implications of MMF

MMF and prosthetic considerations

Median mandibular flexure poses challenging problems for both conventional and implant-supported prostheses. It causes increased stress in dental implant-related prosthesis and abutments, poor fit of fixed or removable prostheses, impression distortion, pain during function, fracture of screws of implants or porcelain crowns, loosening of cemented prostheses, and resorption around implant. Therefore, for better longevity and outcomes of dental and implant-related prosthesis, it is important to reduce MMF (22, 40–56).

Following prosthetic procedures and guidelines should be followed to reduce the effect of MMF.

Considerations in impression making. All prosthetic treatments require an analog of the oral tissues for construction. To make an analog of oral tissue, an impression is made with various impression materials. All impression-making techniques involve a certain degree of mouth opening that depends upon the clinician's objective requirements. As musculature strongly influences the amount of mouth opening and closure, the effect of MMF cannot be precluded in the impression-making process. Moreover, the changes in mandibular width due to the application of pressure on the rigid bone during various procedures for prosthesis reconstruction cannot be neglected. The strong influence of MMF may lead to inaccurate construction of fixed prostheses and removable prosthesis at the time of placement. The usual tendency is to attribute the misfit of the prostheses to the variability of dental procedures without considering the influence of MMF.

The medial convergence of the mandible due to contraction of the muscles by the conventional open mouth impression technique may alter the accuracy of the master cast and result in compromised prosthesis (3, 5). Moreover, when impressions are obtained with mandible at a position of maximum mouth opening, the teeth will be recorded in a more lingual position than they would actually be found at rest or in occlusion (Fig. 2) (3). If an impression of the lower arch is made in such a position, the removable prosthetic appliance fabricated on the corresponding cast would be physiologically acceptable only when the mouth is open. When the mandible is closed, the denture would not fit the outwardly expanding arch as it was constructed on a constricted arch form. Such an ill-fitting denture applies pressure on teeth and the accommodating structures in the immediate vicinity. This would result in tooth pain, subsequent tooth mobility, bone loss and gingival inflammation. Pressure spots may be seen in the areas on which the denture was supported at the time of fitting or within a short range of duration of service in spite of taking into consideration the accuracy and dimensional stability of the impression and die materials. The most common areas of sore spots are seen under the lower denture on the mylohyoid ridge as these areas are under maximum strain during flexure (2). Thus, it is very important to make impressions for lower prosthetic appliances with the mandible as close as possible to the upper jaw. Impressions made using closed-mouth technique result in minimal activation of the muscles of mastication and help to reduce the amount of mandibular deformation.

Similar considerations should be followed when impressions are made for fixed prosthetic appliances as well. Impressions made with mouth wide open may lead to incomplete seating of fixed prosthesis that may later require extensive occlusal correction (2). Gates and Nicholls (1981) (9) concluded that a decrease in arch width of mandible observed during maximal opening, protrusion and biting can be prevented by applying a horizontal retrusive force on the mandible while recording centric relation. The amount of mandibular arch width change during impression making could also be minimised by preventing any protrusive movement or opening beyond 20 mm.

Considerations while recording centric relation (C.R.). Mandibular flexure occurring either during patient-guided C.R. registrations or during function may influence the fit of the prosthesis and make it difficult for the clinician to achieve good occlusal contact (12). This is further complicated by the use of rigid dental casts mounted within rigid articulators (59). This often results in severe discrepancies as a closed-mouth C.R. record may not accurately fit onto a dental cast made from an open mouth impression technique. Secondly, the framework of a fixed dental prosthesis fabricated on a cast made from an open mouth impression technique would not fit accurately in patients' mouth. Such prosthesis would have occlusal interferences and result in pain when the patient applies a biting force. Therefore, a 'closed-mouth' impression technique and a dentist-guided C.R. recording technique should be used to reduce such discrepancies (12). Tylmann (2001) supported a closed bite double arch method to avoid mandibular flexure effects with open mouth techniques (60).

Considerations while occlusal mounting. Mandibular flexure in the horizontal plane often results in discrepancies between cusp tip indentations in the jaw registration records and cusp tip location on the dental casts (12). The articulation of the casts is affected due to the lingual movement of mandibular teeth. This type of occlusal mount will not represent the correct occlusal relationship. The restorations fabricated to such recordings could present with occlusal interferences and articulators may require modification so as to allow for mandibular resilience.

Removable and fixed prostheses. Mandibular flexure can be especially a problem for fixed prostheses. Mandibular flexure may be one of the main reasons for the decementation of long span bridges with respect to abutment tooth in the posterior region (for example, 33–37 or 33–38). Crowns and bridges that are fabricated according to the impressions made under the influence of MMF do not fit accurately in the patient's mouth or may have high occlusal contacts. The mismatch of the dorsoventral shear characteristics of the superstructure and the jaw generates a separating force that breaks the cement seal and intrudes the abutments (10). The resultant torque also harms the periodontal ligament space and results in tooth mobility. The torquing of the materials due to flexure, and/or stress on the cements may manifest as cement failure, porcelain fracture or both, especially in a long span prosthesis. Therefore, a long clinical crowns and well-shaped, high-angled preparations are advisable. It is also recommended to decrease the length of rigid spans and construct large spans of porcelain in discontinuous sections (3, 10–12, 39, 60). Using two or three splits or even using a non-rigid connector, the stresses can be minimised. The other method to reduce distortion is by making the impressions by a stress-free method, in physiological rest position with mouth opening not more than 20 mm.

As mandibular distortion affects the fit of removable partial denture and puts undue stress on the abutment teeth of a bilateral fixed partial denture, prostheses should be fabricated by the sectioning, soldering or using passive fit technique (44–46). The frameworks constructed using the passive fit method induce a significantly smaller amounts of strain on the prosthesis compared with the conventional technique (44, 45). The computer-aided design/computer-aided manufacturing (CAD/CAM) technique that is better alternative to fabricate implant frameworks instead of the casting technique is also influenced by mandibular flexure (46–49). The main problem with CAD/CAM technique is that it its large camera head that cannot be inserted without a wide opening of the lower jaw. However with future improvements in this regard, the effect of mandibular flexure could be reduced with CAD/CAM technique.

MMF and periodontal considerations

The narrowing of the mandibular arch abnormally stimulates periodontal ligament mechanoreceptors with significant influence on the health of the periodontal apparatus and surrounding alveolar bone (Fig. 3a–c) (61).

A rigid splinting is commonly performed on periodontally involved teeth where half to two-thirds of the alveolar bone support is lost. Such a rigid fixed splint will restrict the movement of the mobile teeth.

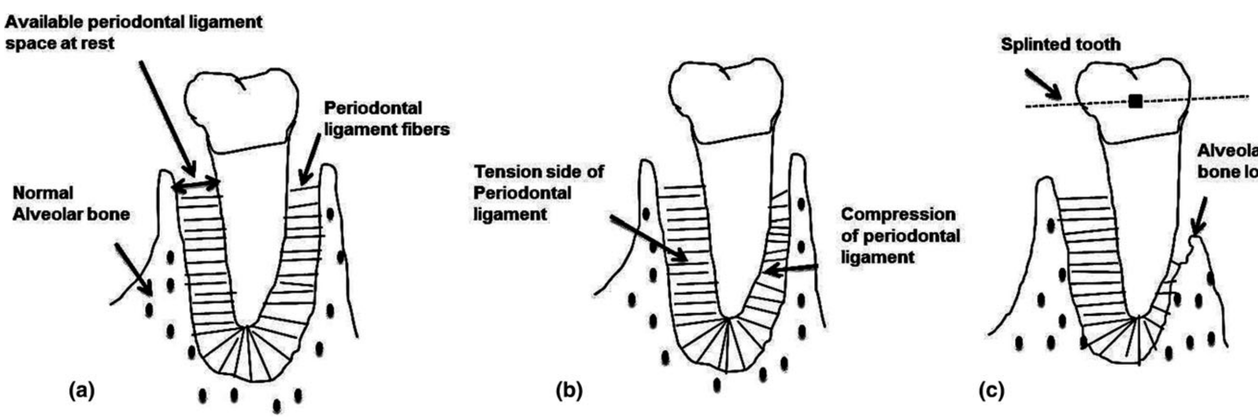

Fig. 3. Effects of mandibular flexure on periodontal ligament apparatus: (a) Available periodontal ligament space at rest with no compression or tension in the periodontal ligament. (b) Tension in periodontal ligament on one side of the rotation of teeth with compression on the opposite side when mandibles flexes medially but not exceed the periodontal ligament space. (c) The clinical attachment loss and alveolar bone loss that result in splinted teeth that resisting mandibular flexure and form severe tension and compression in the opposite sides of periodontal ligament fibres.

In such a situation, the teeth fail to move when the mandible moves in both linear and rotational directions during flexure. This creates stress in the periodontal attachment and causes increased tooth mobility with alveolar bone loss. Fishman in 1976 developed splints for full arch rehabilitation and evaluated the effects of these splints on MMF. He concluded that mandibular flexure would be reduced in most of the cases where rigid splinting was performed and a short span splint with no rigid attachments will probably provide better results (3). However, inhibition of mandibular flexure apparently increases as more teeth are splinted and more rigid attachments are used (Fig. 4a–f) (3, 43). According to De Marco and Paine (4), some forms of stress on prosthesis are constantly present during function with obliteration of periodontal space around natural teeth. However, with use of smaller unit in prosthesis with precision attachments, the amount of stress transmitted due to mandibular flexure to the periodontal attachment apparatus and the prosthesis itself can be reduced. Although mandibular flexure is reduced with rigid splinting, stresses develop around the teeth as they are unable to flex in its original manner along with the mandible. This results in further alveolar bone loss. Thus, mandibular flexure is considered as a contributing factor for the destruction of the alveolar bone (Fig. 3a–c).

MMF and implants

Mandibular flexure potentially affects the accuracy of different stages of implant treatment, including osseointegration of the surrounding bone, implant prosthesis fabrication, strain distribution within the framework during mastication, crestal bone around implants, etc. The flexural forces cause lateral stresses on the implant body resulting in bone loss around implants, loss of implant fixation, material fracture and discomfort on mouth opening. Therefore, it is essential to consider MMF while planning any implant-supported prosthesis (46–58).

Median mandibular flexure causes microdamage at the crestal region and poor osseointegration due to micromovements around implants (Fig. 5). Fischman (1990) explained the importance of rotational aspect of mandible on the osseointegration of implants (3, 22). Hobkirk and Schwab (1991) have also confirmed that the posterior implants could be subjected to stress-induced microdamage at the bone implant interface in cantilever situations due to mandibular flexure. A relative displacement of up to 420 microns and force transmission of up to 16 N between linker implants with jaw movements is possible during mandibular flexure. The forces were more during opening and protrusive movements than lateral excursion (21). A linear distance of implants which

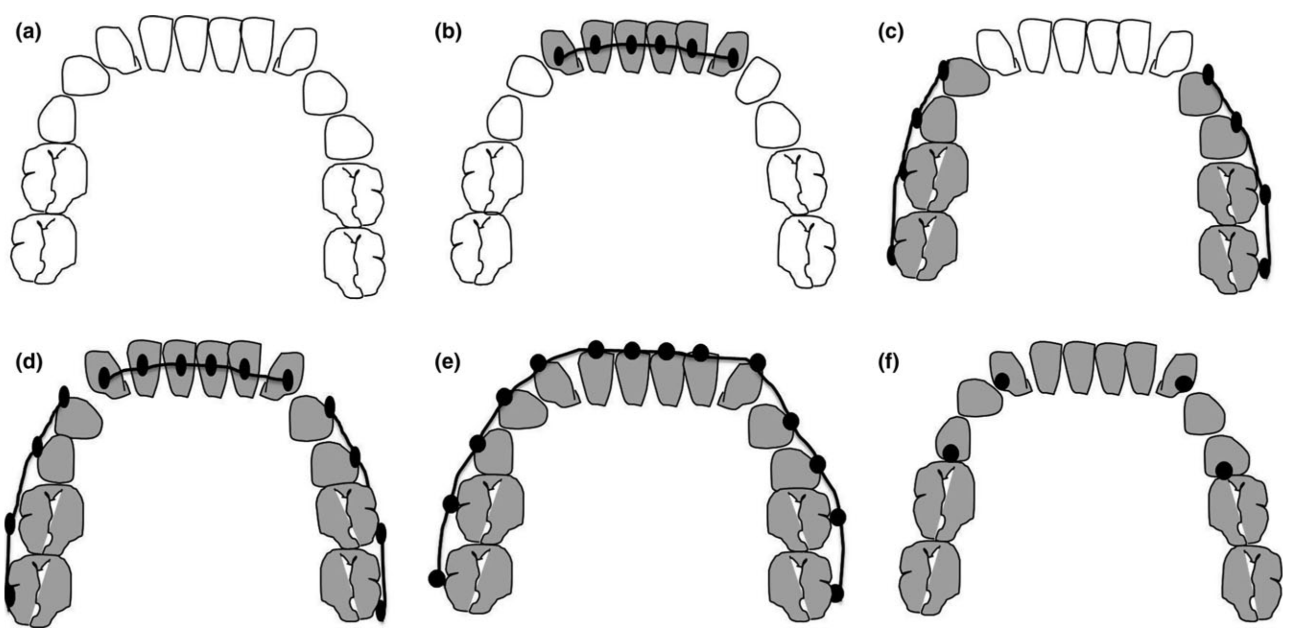

Fig. 4. Effects of different types of splinting during median mandibular flexure: (a) Control (b) anterior splinting (c) Posterior splinting (d) Anterior and posterior splinting (e) full arch splinting (f) Splints with precision attachments.

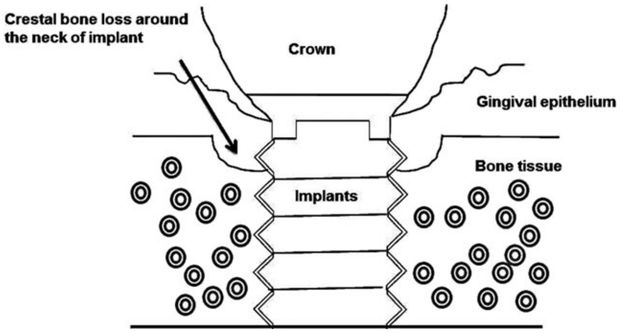

Fig. 5. Crestal bone loss around implants due to mandibular flexure.

had been placed 10 mm apart showed more variation in distance during protrusion compared with maximum mouth opening position (42).

Hobkirk and Havthoulas (1998) studied the influence of functional mandibular deformation on the force distribution in the jaws, implant or superstructure complex. The results showed that the force distribution in the mandibular implant host complex is unevenly distributed about the median sagittal plane as a result of jaw asymmetry and an increase in the number of implants that support a fixed superstructure would results in a leverage effects around the midline (22, 42). Lindquist *et al.* measured the bone loss associated with osseointegrated implants that were placed between the mental foramen and supported fixed restorations with posterior cantilevers using stereoscopic intra-oral radiography. The result confirmed that greater crestal bone loss occurs around the anterior than the posterior implants in the region of the symphysis as the main point of flexure is restricted by the splint (8, 49). A smaller number of implants would be associated with localised patterns of force distribution (49, 62, 63). A mismatch of the dorsoventral shears characteristic of superstructure and jaw may also increase the posterior tensile forces that are associated with unilateral loading and crestal damage (22). Apart from crestal bone loss, considerable bucco-lingual forces are also observed when posterior rigid, fixed implants are splinted to each other in a cross-arch restoration. Thus, considerable stress build up occurs around distal implants and the superstructure around the symphysis due to mandibular flexure with symphysis as a fulcrum (62). Therefore, a division of the superstructure at the level of the symphysis could significantly restore the natural functional flexure of the mandible (62, 63).

Following procedure should be adopted to reduce the effect of mandibular flexure while placing implants: impressions should be made with the patient's mouth in a partially closed unstrained mandibular position; short spans of fixed prosthesis are advisable whenever possible; large spans of porcelain should be avoided. At sites where implant size or bone quality are compromised, posterior mandibular osseointegrated implants should be free standing with short span of fixed prosthesis or related to tooth abutments via stress breakers. Thus, fixed implants and non-rigid connectors with splitting of the restorations should be avoided in the mandible as two or more independent prosthesis are more favourable when implants are placed in the anterior region (57). When an edentulous mandible is restored with an implant-supported prosthesis connected by a metal bar and retained with screw, mandibular flexure may cause screw loosening and needless stress on the prosthesis and implant. Therefore, in order to relieve the stress and improving the longevity of the prosthesis, sectioning of the hybrid prosthesis in the midline should be done (64). Thus, the splinting of implants or using materials with a high modulus of elasticity as frameworks could also improve implants stability. It has been shown that splinting natural teeth reduces the amount of mandibular flexure, and the degree of inhibition is proportional to the number of teeth splinted and rigidity of the splinting material (3).

Unlike natural teeth where periodontal ligament absorbs some of the displacement transferred to the mandible and reduces the amount of mandibular flexure, osseointegrated implants transfer all the stress to the mandible. Thus, more bending of the mandible is expected during jaw movements. When implants are splinted, the restriction in the amount of mandibular flexure can be assumed to be at least equal to, if not more than, a splinted natural dentition. Therefore, rigid splinting is often required in implant dentistry to distribute the stress on each fixture and to restrict the amount of mandibular flexure during function (26, 53–55).

A rigid splinting of anterior teeth to mandibular implants placed posteriorly will probably experience a greater amount of torque at the crestal bony region surrounding the implant. This torque could manifest as bone and implant loss, material failure demonstrated by cement or screw fracture, or more seriously as metal fatigue of the implant, prosthesis or their connecting elements. In such situations, shorter prosthetic spans or stress breakers should be considered and implants should not be splinted to natural teeth (65). As the amount of flexure with a rigid splint in the anterior region (i.e. canine to canine) is less, the long-term success of osseointegrated implant splinted together with fixed prostheses between the mental foramina is also satisfactory (8). The reason for this may be that the strength of the osseointegration bond is a more viable one than the detrimental effects of mandibular flexure. However, when anatomic considerations are questionable and implants selected are of smaller size with a strong opposing occlusion, the effect of mandibular flexure become more significant (49–55). Thus, it very important to choose the most favourable implant designs for a particular site.

Mandibular flexure is known to vary for different implant designs as implant configuration can affect the distribution of stress within prosthesis. A rectangular-shaped beam with a smaller width is known to generate less stress than I- or L-shaped bar (49). Itoh *et al.* (2004) investigated the difference between a straight and an offset configuration using a photoelastic model and found a change in stress distribution using the offset configuration. A staggered arrangement reduced the stress on the anterior and posterior implants compared with the straight arrangement; however, the middle implant was subjected to more stress (51, 52).

The nature of the prosthetic material also influences the mandibular movement. Suedam *et al.* compared the use of precious and non-precious metal alloys for the fabrication of implant frameworks (53). They found that material of a lower modulus of elasticity, such as palladium–gold (Pd-Au) alloy, was much better in reducing stress while materials with a high modulus of elasticity like cobalt–chromium (Co-Cr) were more resistant to bending forces. Thus, there was more intense stress at the terminal abutment with cobalt–chromium than palladium–gold. However, the rigidity of the material used for the construction of prosthesis or for splinting of fixture was not significant, especially if each fixture was able to carry the full load applied to it (26, 52, 57). The use of a sectional prosthesis design, such as multiple implant-fixed dental prostheses or a prosthesis divided along the symphysis region, can be considered to minimise the effect of mandibular flexure (57, 66). The extent of flexure with various materials is not known and is an area of further research (54, 55).

Conclusion

Mandibular flexure is a multifactorial phenomenon that occurs instantaneously and concurrently with jaw movements. The mandibular flexure can affect the prognosis and treatment outcome for various dental and implant-related procedures. Therefore, it is very important to take appropriate measures and adopt correct technique that helps negate the flexural movement of the jaw during any prosthetic rehabilitation. This would not only help clinician to achieve good prosthesis with accurate fit but also help to maintain the health of the surrounding periodontal and osseous tissues. For better prognosis and stability, new techniques and modifications for oral rehabilitation by fixed and removable prosthesis and implant design are warranted to reduce the effect of mandibular flexure.

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