Biomechanical Aspects of Prosthetic Treatment of Structurally Compromised Teeth

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Purpose: This article presents clinical guidelines for restoring structurally compromised teeth and dentitions to reduce the risk for fatigue-caused failures in connection with prosthetic reconstructions. ***Materials and Methods:*** Based on the best scientific evidence available and clinical expertise acquired through experience and practice, biomechanical principles are elucidated from a prosthetic aspect. ***Results:*** In prosthetic treatment in the structurally compromised dentition, all efforts need to be focused on protecting the abutments and reconstruction from future fatigue failures. A modified, "therapeutic" occlusion to avoid nonaxial forces may then be prudent. ***Conclusion:*** By lending the prosthesis a favorable occlusal design, the nonaxial forces may be markedly reduced, and the teeth, cement, and restorative materials will be less susceptible to fatigue failures. *Int J Prosthodont 2004;17:135–141.*

The tooth anatomy in the natural dentition is strongly correlated to the original needs. In the posterior parts of the dental arch, where the loads are great and mainly axial, the teeth have diverging roots and stand like straddle-legged platforms in the jaw, ready to stand up against bite forces of nearly 400 N.[1–3] In the maxillary anterior region, the function and force direction are different, and the anatomy is adapted to withstand both axial forces at biting off and lateral forces. The greater the vertical overbite, the greater are the lateral forces during function. To manage the occlusal functional loading, the anterior teeth are provided with single, long, pole-shaped roots. The maxillary canine is the most striking example, as it alone may successfully tackle all axial and lateral forces by laterotrusion, and the root of the maxillary canine normally has the greatest dimensions in the dentition.

This ingenious system works well as long as the dentition is intact. However, loss of tooth structure or loss of teeth may change the situation dramatically, and the strength of the teeth is a direct function of the amount of remaining tooth structure.[4] Hence, when prosthetic treatment is planned in the mutilated dentition, attention should focus on protecting the structurally damaged teeth from high functional loads to avoid technical failures. The therapeutic goal is not to reestablish the original anatomy, but to provide the patient with a socially acceptable tooth-like reconstruction, with an occlusal design protecting the supporting units and reconstruction from overloading.

Well-executed fixed partial dentures (FPD) may function for a very long time. Survival rates of 79% to 65% after 18 to 23 years in service have been reported,[5,6] and a meta-analysis calculated the survival rate of FPDs from seven different studies to be 74% after 15 years.[7] The reasons for removal of FPDs may be biologic or technical; among the technical reasons, some risk factors have been concluded from clinical studies. Endodontically treated abutments constitute a higher risk for failure according to several studies,[6,8–10] and cantilevered FPDs often exhibit reduced survival rates.[11–15] Horizontal stress on restorations and abutments is a well-known risk factor from general mechanical principles and from clinical experience.[16]

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Several guidelines for a "therapeutic occlusion" have been presented and include the following recommendations[17–19]:

- Stable jaw relationships with bilateral contact in retrusive closure
- Axially directed forces
- Smooth function without disturbing or harmful intermaxillary contacts during lateral or protrusive excursions

Based on the best scientific evidence available and clinical expertise acquired through experience and practice, the aim of this article is to present clinical guidelines for restoring structurally compromised teeth and dentitions to reduce the risk for fatigue-caused failures.

Materials and Methods

A literature search was conducted using MEDLINE/PubMed for the years 1970 to 2003. The focus of the search was on dental prosthesis failure, biomechanics, dental occlusion, occlusal force, and post-and-core techniques. In addition, some common textbooks on the subject were scrutinized for further documentation. Adding the experience from specialist clinics to the best scientific evidence available, failed prosthetic reconstructions in patients referred by general practitioners have been analyzed.

Mechanical Fatigue

Technical failures in connection with fixed prosthodontics are as a rule caused by fatigue fractures. The tooth, cement, and restorative materials are subject to repeated stresses over a long period. When a material—dentin, cement, or restorative material—is subjected to intermittent tensional stress, a small crack may develop that slowly grows until a fatigue-caused fracture occurs.[20]

The following factors influence the risk for fractures caused by mechanical fatigue:

- Magnitude and frequency of occlusal loads
- Direction of forces
- Dimension and shape of dentin and restorative materials

Magnitude and Frequency of Occlusal Loads

To reduce the magnitude and intensity of the occlusal loads for patients with high functional loads is a challenge, but it is of the utmost importance for the prognosis of all types of prosthetic treatments. Parafunctional habits require special attention, as a high risk of fatigue failures may be expected. This is not only due to increased load levels, but also to prolonged loading times and an increased number of loading cycles.[16–21] Whenever increased occlusal or incisal tooth wear is visible, or other clinical signs of parafunctional habits exist, these should be diagnosed and evaluated in the pretreatment examination. If an extensive prosthetic rehabilitation is planned, care should be taken not to build in occlusal interferences in the new reconstruction. Any occlusal interference outside the prosthetic reconstruction should also be eliminated to avoid unnecessary stresses on the reconstruction.

Direction of Forces

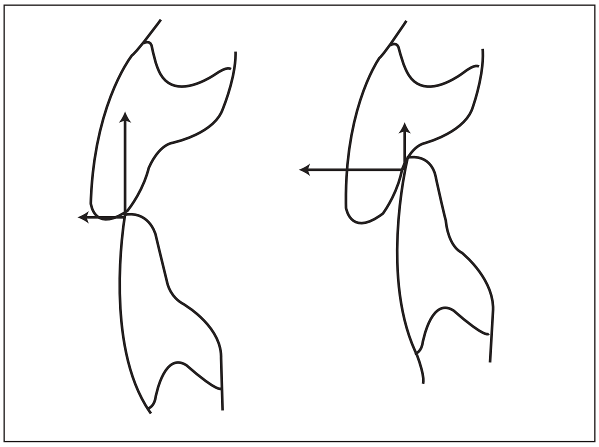
Tension stress, not compression, causes fatigue fractures. To change the direction of the stress from tension to compression is an efficient way to avoid fatigue-caused fractures of teeth and restorative materials.[16,20,22]

A structurally compromised tooth with complete coronal coverage, including a sufficient metal collar embracing the circumference of the root (a ferrule effect), may well withstand forces through the long axis of the tooth. The developed stresses are mainly compressive and are evenly distributed over the supporting structures, in contrast to situations with forces in transverse directions, where tension stress occurs. The horizontal forces are hazardous to the weakened tooth, cement, and reconstruction; by minimizing the nonaxial forces, the risk of fatigue fractures may be reduced.

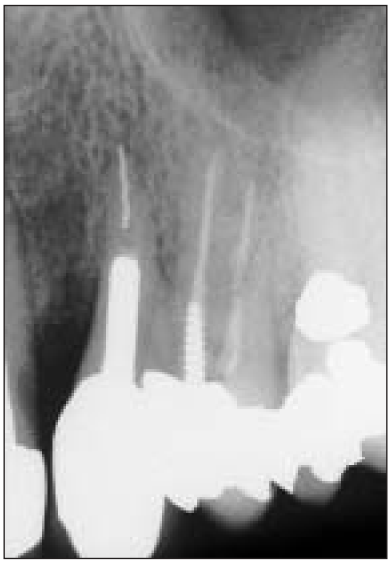
Endodontically treated teeth restored by means of posts and cores hold a prominent position in this respect because of their generally extensive loss of tooth structure. During a 5- to 7-year period in a Swedish population, teeth with posts consequently were extracted more frequently than other teeth.[23] Similar findings are reported in a follow-up study 18 years after prosthetic treatment.[9] Failures in post-retained crowns frequently occur in the maxillary anterior region, where the horizontal forces often are great,[23–27] and the maxillary anterior region is therefore considered to be a high-risk area for technical failures.

A deep vertical overbite produces high horizontal stress on the maxillary anterior teeth in protrusive and lateral excursions (Figs 1 and 2). When planning prosthetic treatment in a case with a deep overbite, an evaluation of the stress-bearing capabilities of the teeth needs to be done. In such an evaluation, structurally compromised teeth might be judged incapable of resisting high lateral stress, and special attention is then needed to protect the teeth from future fatigue fractures, eg, by reducing the lateral stress in the reconstruction by a modified occlusal design.[28] The posterior teeth will play an important protective role in both central occlusion, where they contribute to occlusal stability, and in

Fig 1 Deep overbite *(right)* increases horizontal forces and should be avoided in prosthetic reconstructions of structurally compromised teeth. In a deep overbite situation, the vector of force in lateral and protrusive excursions is maintained in an almost horizontal direction.



Figs 2a to 2c *(right and below)* Long and too-wide post has been inserted in maxillary left canine. General guideline of at least 1 mm of dentin surrounding the post has not been followed, and the tooth needs protection against root fracture. Instead of adjusting the mandibular occlusal plane by incisal grinding on the mandibular lateral incisor and canine and designing the maxillary canine crown for group function, crown is designed for canine "protection" and is thereby subjected to high lateral forces in articular movements. One year after cementation, root fracture was diagnosed by a local deep periodontal pocket, and the tooth was extracted.



laterotrusion, where they may be brought into group function to help share the horizontal forces. Loss of the posterior teeth in a dentition with a deep vertical overbite may increase the forces on the anterior teeth. It is thus important to maintain the posterior teeth in cases with a combination of deep overbite relations and low resistance to horizontal forces.

When a prosthetic treatment on structurally compromised teeth in the maxilla is planned, one way of changing the direction of stress from tension toward compression is illustrated in Fig 3. After creating an optimal orientation of the occlusal plane by preprosthetic incisal/occlusal grinding in the mandible, the patient is provided with an FPD designed with shorter maxillary

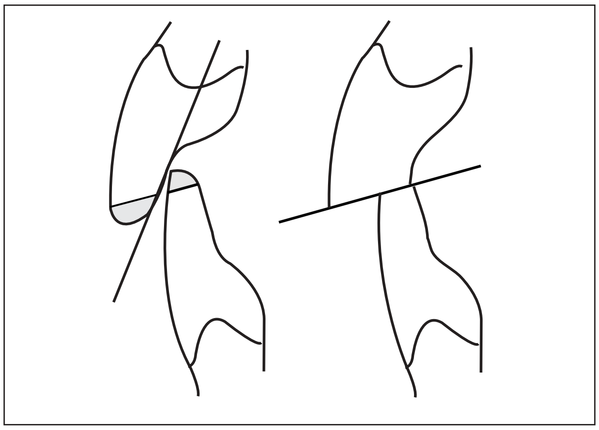


Fig 3 Design of artificial crowns does not always need to correspond to natural teeth. A "therapeutic occlusion" in the structurally or periodontally compromised dentition may create a favorable direction of functional forces.

Fig 4 Control of movements of uncemented maxillary cross-arch FPD with optimized occlusal design in structurally and periodontally weak dentition. Note also the mandibular preprosthetic adjustment of the occlusal plane.

anterior teeth and broader incisal edges than in the original anatomy, often combined with a moderate increase of the vertical dimension. By this reduction of the cuspal inclination and by distributing the forces evenly in articular and protrusive movements, the direction of the functional forces will be brought into a more axial direction. The effect of these measures can clearly be visualized by letting the patient perform articular movement with the uncemented FPD in place (Fig 4). With the fingers as sensors, the operator feels the stresses that will act upon the tooth, cement, and reconstruction after cementation. The tendency for the FPD to tilt during jaw movements will be an approximate measure of future stresses.

In some situations, it may be useful to convert the occlusal design of a maxillary canine into a shape between a canine and a premolar. This strategy can be used when the posterior teeth are weak and the canine is needed to share the axial forces as well as give protection to the anterior teeth in laterotrusion.

Prosthetic treatment in situations with both a large overjet and deep overbite is demanding. Orthodontic and/or surgical treatment preceding the rehabilitation may in such cases achieve a change in the interocclusal relationships for markedly reduced lateral forces (Fig 5).

Figure 6 illustrates a case where a single post-retained crown was planned for the maxillary right canine. Parafunctional habits, deep overbite, and lack of coronal tooth structure were factors complicating the treatment. Good periodontal support and very low tooth mobility also contributed to the risk of root fracture, and a surgical crown-lengthening procedure was recommended to facilitate incorporation of a proper ferrule effect of the crown. As several biomechanical risk factors were present, the planned crown was designed for group function to minimize the nonaxial loads on the weakened tooth, although this would compromise the esthetic outcome in this case.

Whenever a modification of the occlusal design is planned, the new intermaxillary relationships should be established in a provisional prosthesis to facilitate evaluation for both the clinician and the patient. It is important to involve the patient in the risk-benefit discussion, as he or she might need to accept both a changed esthetic appearance and altered function. A wax-up on mounted models is useful to both illustrate for the patient and plan the design. The dental technician also needs some concept of preferred occlusal schemes if appropriate interocclusal relationships are to be incorporated into the superstructure.

Tension stress develops in the luting cement when abutments included in the same reconstruction show different degrees and directions of mobility. The abutment teeth exhibiting the smallest degree of mobility take up most of the functional force. The mobility will decrease after splinting the teeth in an FPD, but the stress will still be present, just transferred to the cement, with a risk of a fatigue fracture.[28] Therefore, splinting maxillary anterior teeth with different degrees of mobility in an FPD in a case with high horizontal forces creates a biomechanical risk if the occlusal design is not modified, as described above.

Dimension and Shape of Dentin and Restorative Materials

The lower the amount of tooth structure that remains, the lower the tooth's fracture strength and the more effort will need to be focused on minimizing the functional stress on both the tooth and the prosthesis. The

Figs 5a and 5b Seventy-year-old woman with angle Class II malocclusion. The dentition has functioned satisfactorily for many years, but after loss of posterior teeth, occlusal forces acting upon remaining structurally compromised teeth are too great and result in technical failures on both maxillary FPDs. Rehabilitation with acceptable prognosis in existing interocclusal relationship is not possible, and large overbite complicates treatment. In this case, mandibular surgical advancement and some preprosthetic incisal grinding were performed to create a platform for maxillary FPD.

Figs 5c to 5e *(right and below)* Maxillary metal-ceramic restoration was finally designed to minimize horizontal forces to protect supporting units from future fatigue failures. Situation 6 years after prosthetic treatment is shown. (Prosthetic treatment by Dr Ove Esselin.)

possible future loads consequently need to be considered at the planning stage.

Biomechanical failures on endodontically treated teeth restored with posts and cores are among the most frequent prosthetic failures.[6,8,10,13,29] Caries, endodontic treatments, and post preparations result in generally extensive loss of tooth structure, and consequently endodontically treated teeth are not as able to withstand occlusal forces as vital ones. Several studies report that post treatment does not improve fracture strength,[30,31] and it is the overall opinion among experts today that preservation of both radicular and coronal tooth structure is one of the most important factors to protect the tooth from a fatigue fracture. If a post is not necessary for retention of the crown, it should thus be avoided.[32–36]

A fatigue fracture of the root canal post may happen. It is, however, not recommended to prevent post

Fig 6 Post-retained crown is planned on maxillary right canine. Treatment plan includes surgical crown lengthening; occlusal grinding of opposing tooth; insertion of serrated post with maximum 1.25-mm diameter and a cast core; and crown with 2-mm cervical collar embracing the root, designed for group function in articular movements.

fractures by increasing the post diameter. Instead, creating a proper ferrule—to create compression, compensating for tension stress and reducing the lateral occlusal forces—is a preferable way to avoid post fractures. It is not more metal, but more tooth structure, that strengthens the root.[22]

When a post and core–retained crown gets loose, it generally loosens in one piece. Hence, once the crown is cemented, the post and core and the crown may be regarded as one unit. The unit gets retention both from the coronal dentin and from the root canal, and the more coronal tooth structure that remains, the less is the need for additional retention from the root canal. The stress causing fatigue fracture of the cement is the same as the stress affecting the abutment and the reconstruction. The weakest link is the one to fracture when the stress is unfavorable.

Further aspects of treatment of endodontically treated teeth will be discussed in a forthcoming review.[37]

Conclusions

- Fractures of teeth, cement, and restorative materials are usually fatigue-caused fractures.
- Preservation of tooth structure is essential to avoid root fractures.
- An efficient way to minimize the risk of fatigue fractures is to reduce the lateral occlusal forces.
- To lend the prosthesis a favorable occlusal design is probably far more important for the survival of the endodontically treated tooth than the type of post used.

Acknowledgment

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Literature Abstract

Enhancement of osseointegration of implants placed into extraction sockets of healthy and periodontally diseased teeth by using graft material, an ePTFE membrane, or a combination.

Immediate single-tooth implant placement with transgingival healing should solve the problem of extensive postextraction alveolar bone resorption and the loss of gingival papillae. This study determined whether the addition of a bone substitute and/or GBR membrane to the site of an immediate implant would increase the development of lamellar bone, particularly in the presence of bone defects. Four treatment modalities associated with immediate placement of hydroxyapatite-coated endosteal screw implants into extraction sockets of healthy (C/H) and periodontally diseased teeth (T/PD) were tested. Five dogs with healthy teeth and five dogs with naturally occurring periodontitis were chosen. Each dog received eight implants after extraction of four mandibular and four maxillary premolars. Four implants were submerged for 3 months and four for 6 months. Implants were placed alone (subgroup A), surrounded by a Gore-Tex membrane (subgroup B), surrounded by PepGen P-15 at the coronal area (subgroup C), or surrounded by a combination of graft material and the e-PTFE membrane (subgroup D). Implants in subgroup A were osseointegrated in both C/H and T/PD groups, with similar bone-implant contact ratios. Adding graft material (subgroup C) significantly increased the bone-implant contact ratio of all mandiblar and maxillary implants in the C/H and T/PD groups compared with the ratio for subgroup A at 3 and 6 months. However, by 6 months, the bone-implant ratio for subgroup B caught up with that of the subgroup C implants. The graft material and membrane combination (subgroup D) further improved the implant-bone ratio and significantly increased lamellar bone in crestal bone of all implants. This study provides experimental evidence in support of use of a graft material with immediate implants, particularly with bone defects that initially reduce the bone-implant contact ratio. Adding an e-PTFE membrane to the graft material resulted in greater replacement of woven bone by lamellar bone. Clinical trials in humans are recommended as a follow-up.

Tehemar S, Hanes P, Sharawy M. *Clin Implant Dent Relat Res* 2003;5:193–211. **References:** 18. **Reprints:** Dr Mohamed Sharawy, School of Dentistry, AD 1411, Medical College of Georgia, 1120 15th Street, Augusta, Georgia 30912-1122. e-mail:msharawy@mail.mcg.edu—*Myung W. Brian Chang, Lincoln, Nebraska*