Principles of occlusion for implant prostheses: guidelines for position, timing, and force of occlusal contacts

R. J. Chapman, DMD*

Introduction

The introduction of osteointegrated implants in the early 1980s[1] altered the way in which partially and fully edentulous patients are treated prosthetically. Dentures are more stable with attachments on the implants, and implants can act along with the natural dentition as abutments[2] or can stand alone to support fixed prostheses.[3] The development of an appropriate occlusion plays a vital role in the success of both the implant and prosthesis attached to it.

Occlusion is critical for implant longevity because of the nature of the attachment of the bone to the titanium-surfaced implant. In the natural dentition, the periodontal ligament has the capacity to absorb stress or allow for tooth movement, but the bone-implant interface seemingly has no capacity to allow movement of the implant. Any stress from occlusion must be borne totally by the interface. If occlusal force exceeds the capacity of the interface to absorb stress, the implant will fail.

It has been demonstrated that occlusal forces exerted by implant prostheses and natural teeth are similar,[4] and that the discrimination of occlusal forces between edentulous and dentulous subjects is similar,[5] but the ability of the bone-implant interface to withstand specific ranges of occlusal stress, especially during initial loading with the prosthesis, is not completely understood. If the thin polyglycan interface between the implant and the bone is disrupted, either by a sharp impact force or a continual excessive force at some lower level, it is unlikely that the bone will regenerate, and the implant will eventually be lost.

The posterior cantilever can contribute undue stress to the bone-implant interface. Cantilevers are developed because there is often insufficient bone to insert implants posteriorly. Although cantilevers involving the natural dentition do not create the amount of force previously thought,[6] cantilevers from implant abutments might, in certain circumstances, create excessive stress on the implant. For instance, Laurell and Lundgren[7] have recently shown that a contact 80 μm high significantly increases resultant forces on cantilevers.

The lack of shock-absorbing capability at the bone-implant interface can create problems for the prosthesis. The screws that hold many prostheses to implants or the frameworks themselves can be overstressed and fracture if improperly loaded. If the prosthesis is cemented to the implant abutment, stress caused by deflective contacts may create shear stress on the cementing medium and failure of the cement. In implants that have an internal shock absorber, excessive occlusal stresses can cause fracture of the shock absorber.

Occlusal goals for implant prosthodontics

Because of the special conditions unique to implants, it is important to develop an occlusion that places minimal stress on both the bone-implant interface and the prosthesis. Continual stress from interfering occlusal contacts that develop unnecessarily high occlusal loads must be eliminated, and heavy occlusal forces developed on cantilevers or any other segment of the prosthesis should be equalized throughout the entire prosthesis.

* Clinical Professor; Head, Fixed and Removable Partial Prosthodontics; Director, Implant Prosthodontics, Implant Center, Tufts University School of Dental Medicine, One Kneeland Street, Boston, Massachusetts 02111.

Minimal occlusal goals for implant prosthodontics are *(1)* bilateral simultaneous contact; *(2)* no prematurities in retruded contact position (RCP); *(3)* smooth, even, lateral, excursive movement with no nonworking interferences; and *(4)* equal distribution of occlusal forces.

Bilateral simultaneous contact is the accepted standard of an ideal occlusion.[8] It is the most important factor in the construction of occlusion and is of particular importance for implant prostheses. In addition to the potential for neuromuscular dysfunction that premature contacts can create,[9] occlusal force is increased when a high or premature contact is present.[7]

Freedom from retruded contact position to intercuspal position (IP) has long been advocated by Dawson[10] because contact in RCP during certain functions does occur.[11] However, it may also be necessary to create an occlusion free from prematurities in IP.

Deflective contacts in IP may often be responsible for excessive force development. Gibbs et al[12] reported that the greatest forces during chewing are exerted in IP. If this position is unstable because bilateral simultaneous contact was not properly established at the time of prothesis insertion, intolerably high forces could be exerted. Gibbs et al[13] have also indicated that chewing forces are lower with anterior guidance factors, ie, canine guidance, than with posterior guidance. Thus, potentially destructive forces can be minimized by creating canine and anterior guidance wherever possible.

In addition to the minimal goals stated above, ideal occlusion for implant prostheses should also include *(1)* freedom from deflective contacts in IP; and *(2)* anterior guidance whenever possible.

Methods for evaluating ideal occlusion

With current methods, bilateral simultaneous contact can be obtained only with great difficulty because there is no quantitative method for comparing the timing of tooth contacts bilaterally.

The only available method of practically assessing force is through the use of photocclusion wafers.[14] This method, although quantitative, is time-consuming and requires much training to interpret the birefringent patterns produced by the occlusal contacts.

A recently developed computerized device (T-scan, Tekscan Corp) uses both time and force to quantify occlusal contacts.[15] Its use enables refinement of an occlusion that is bilateral and simultaneous in RCP or IP. The computer identifies balancing contacts and displays the magnitude of occlusal forces so that they can be appropriately distributed.

The T-scan is a computer with a color monitor (Fig 1) that uses a sensor technology to quantify the occlusal contact data. The sensor is made of two layers of 25-μm-mylar film printed with horizontal and vertical silver traces to form a grid pattern (Fig 2). A force ink between the silver traces allows increased current flow between the traces when pressure is applied. A minimal current level is interpreted by the software as a contact. Because a 70-μA current is cycling through the sensor every 0.01 seconds, the time of any occlusal contact can be determined within a 0.01-second time frame.[15] The distance between the silver traces is 1.25 mm; therefore the location of any occlusal contact registered will be within a radius of 0.67 mm.[16] Software displays both the timing and force of the occlusal contacts in two separate modes.

Time mode

The time mode immediately displays all the contacts and highlights the first three contacts with their relative time values (Fig 3). Contacts can also be looked at graphically in the three-dimensional display to examine the time differences qualitatively (Fig 4).

Force mode

When the patient closes on the sensor in the force mode, electrical resistance decreases as occlusal pressure is applied.

The resistance change calibrated to display the lowest force level is approximately 100 g at any one contact point; the upper limit of force discrimination at any one point is 1.1 kg.[17] The different levels of force are displayed on the three-dimensional screen as variations in height of the columns (Fig 5). This visual display provides information for appropriate placement of occlusally generated forces relative to both the bone-implant interface and prosthesis.

Occlusal records

The computer also prints records using a thermal printer. Any screen displayed on the monitor can be printed. This creates a history of the patient's occlusion on the implant prosthesis for occlusal contact timing, position, and force.

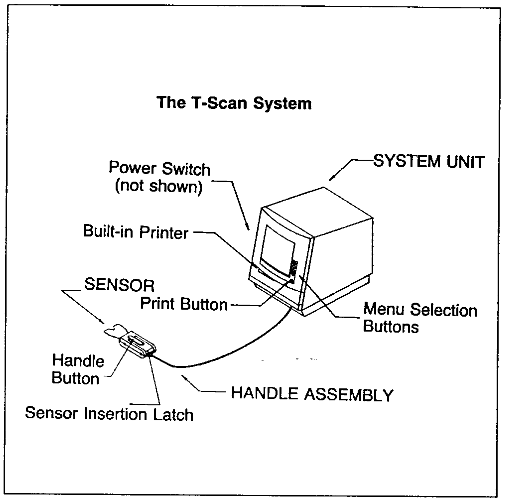

Fig 1 The T-scan: a computer that processes occlusal information.

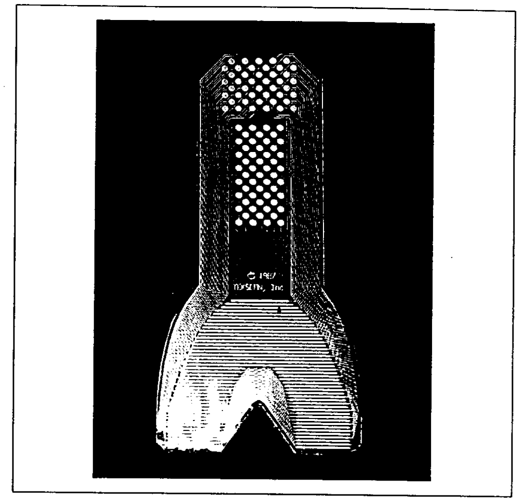

Fig 2 The sensor.

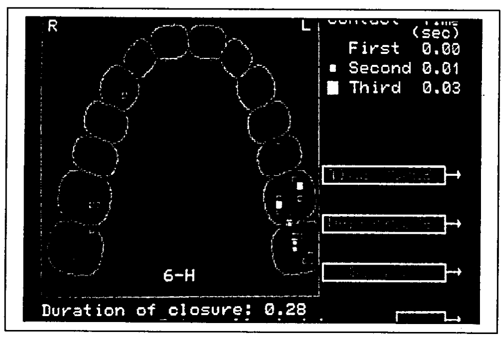

Fig 3 The first contact is identified by the red square on the right on the distal surface of tooth 17. The second contacts are on the left side in the center and the mesial surface of tooth 27 and are identified by the white square enclosed by red. The third contacts are also on the left side on tooth 26 and are shown as white squares. The first contact is always at time zero. For this patient, the second contacts occurred 0.01 second after the first. The third contacts occurred 0.03 second after the first contact. The time values of the remaining contacts, outlined in blue, can be identified by pressing the time scale button. The total duration of closure for this patient is 0.28 second.

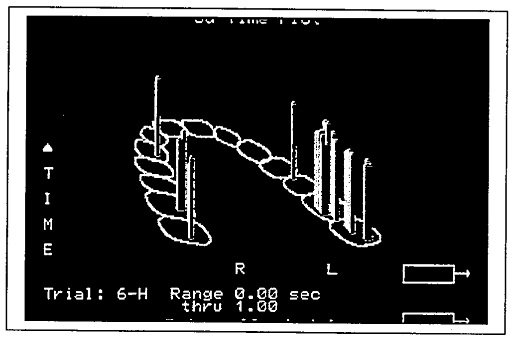

Fig 4 Graphic representation of the timing of the occlusal contacts seen in Fig 3.

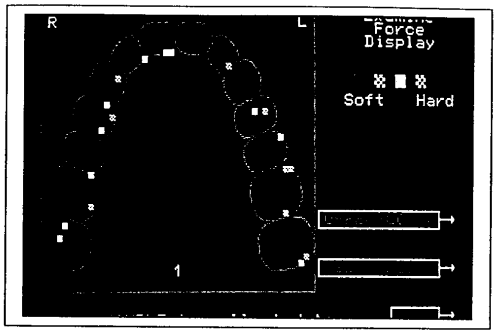

Fig 5a Quantitative force levels are displayed on the two-dimensional display.

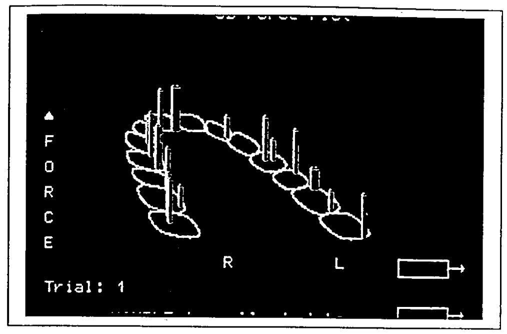

Fig 5b More qualitative evaluation is possible with the three-dimensional display.

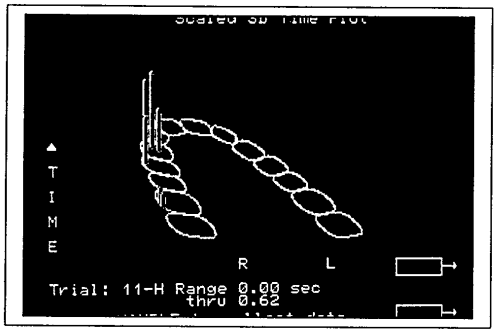

Fig 6 Right lateral excursive contacts shown by the three-dimensional display.

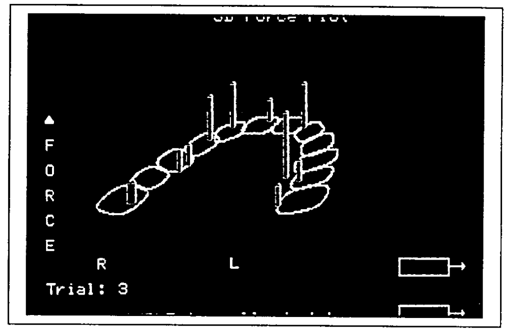

Fig 7a Forces on a distally cantilevered complete-arch implant reconstruction before adjustment.

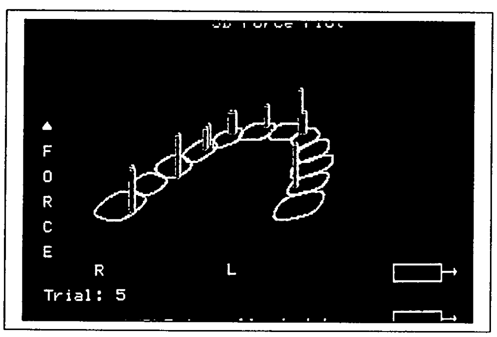

Fig 7b Forces on the same patient after adjustment.

Clinical application

Following are uses for the T-scan in implant prosthodontics:

1. Establish bilateral simultaneous contact at the time of insertion
2. Develop smooth, even lateral contacts
3. Equalize the force of the final contacts
4. Provide records to monitor occlusal contacts over time for both bilateral simultaneous contact and force distribution

Establishing bilateral simultaneous contact

Premature contacts in RCP and IP must be eliminated. When contacts are bilateral and simultaneous, there can be no sliding contacts that could result in excessive lateral loads on either the bone-implant interface or the prosthesis. Premature contacts are identified so that they can be eliminated, thus providing better control of force on both the bone-implant interface and the implant-prosthesis system.

Lateral excursive contacts

Evaluating and developing lateral guidance from IP with no balancing or interfering contacts is also possible. The lateral excursive contacts are graphically displayed on the three-dimensional display (Fig 6).

Adjusting force on implants

The force mode is used to identify the load on the implant prosthesis at any occlusal contact. Force is a factor of both the intensity of the contact and the area of the contact. If an individual contact is too large or there are too many small contacts that together would produce a large force, the resultant stress to the bone-implant interface or the prosthesis may be destructive. The force mode identifies the relative amount of force and equalizes those forces as appropriate (Fig 7). In particular, occlusal contacts on cantilevered pontics are adjusted so that the force is lessened on the pontics, and the majority of the force is directed over the implant sites.

Record keeping

As in good recall systems for conventional prosthodontic care, implant prostheses should be evaluated on a routine basis for the health of the peri-implant tissues and the bone level surrounding the implants. In addition, the record keeping capability of the printer allows the dentist to follow the occlusion on implant prostheses longitudinally and intercept any pathologic changes before damage occurs.

Occlusal design for implant prostheses

There are two major types of implant prostheses: removable and fixed. Much like attachment partial dentures, the detachable/removable prostheses rely on some type of attachment for retention to the implants. The fixed/removable type are actually fixed partial dentures that can be removed from the implant directly by removing the retention screws. Although the occlusal requirements of these prostheses are similar, each requires special consideration.

Occlusion on detachable implant prostheses

The most common of the implant-retained prostheses is the mandibular denture. Two implants placed in the canine region with a retentive attachment fixed to the implants dramatically aids in retention of the denture. Opposing maxillary dentures are often not implant-retained, so the occlusion developed to aid stabilization is bilateral balance along with bilateral simultaneous contact. If monoplane teeth are used, bilateral simultaneous contact is all that is necessary for stabilization.

If, however, the maxillary denture is also retained by implants, canine guidance over the implants is recommended (Fig 8). Bilateral balance is developed only as an aid in stabilizing dentures to prevent loss of atmospheric seal. If retention does not depend on atmospheric pressure, bilateral balance might be as destructive to the bone-implant interface as it can be to the periodontium in natural dentitions. It is, therefore, desirable to develop an occlusion that reduces torquing forces by placing lateral excursive forces directly over implants whenever possible. Because of bone thickness and height, implants are usually placed in the canine areas. The most appropriate occlusal scheme, therefore, is canine guidance when implants retain both maxillary and mandibular dentures. Whether bilateral balance or anterior disclusion is developed, the lateral contacts should be smooth, even, and harmonious.

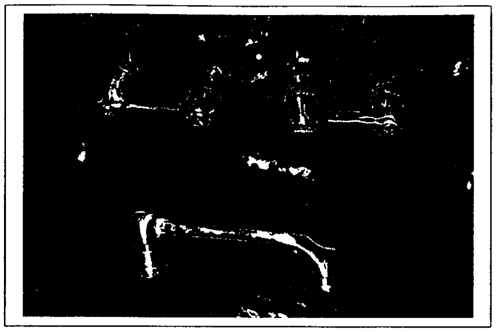

Fig 8a Four maxillary and two mandibular implants supporting bars that retain removable prostheses.

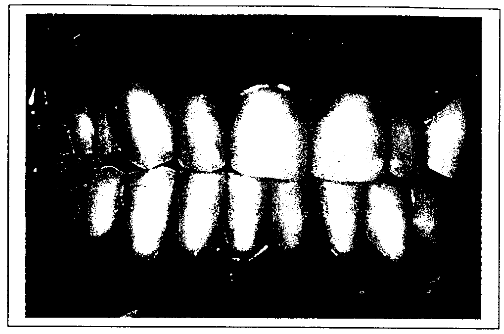

Fig 8b Shallow canine guidance on the prostheses attached to the bars shown in Fig 8a.

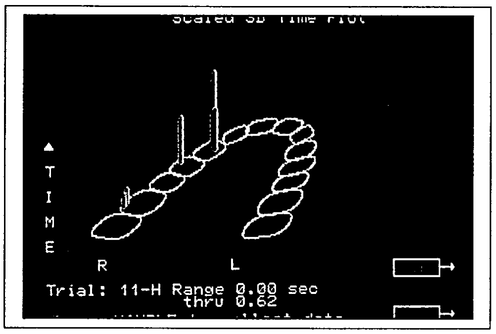

Fig 8c Three-dimensional display of guidance in Fig 8b.

Fig 9a Four-unit fixed prosthesis supported by the two maxillary distal extension implants and attached to the canine with a precision attachment.

Fig 9b Canine discludes the prosthesis in lateral excursions.

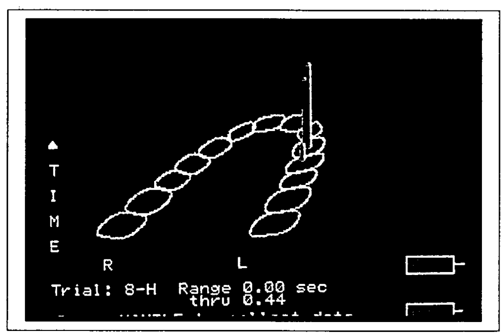

Fig 9c Three-dimensional display of the lateral guidance seen in Fig 9b.

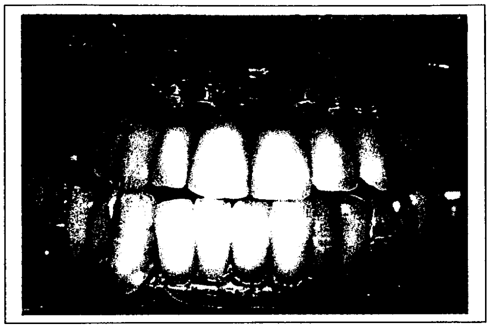

Fig 10a Canine guidance on a maxillary implant reconstruction.

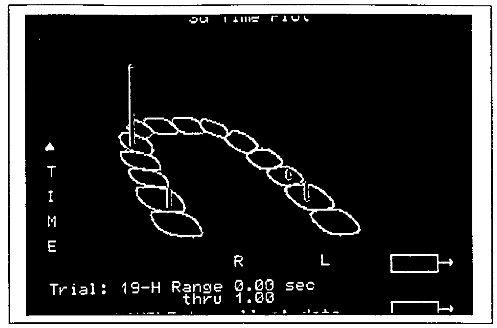

Fig 10b Three-dimensional display of guidance seen in Fig 10a.

Fig 11a Distal cantilever on maxillary implant complete-arch reconstruction.

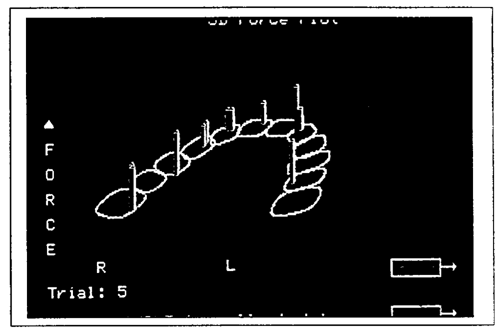

Fig 11b Forces equalized so that the cantilevered segments receive the lowest levels of force.

Occlusion on implant-retained fixed prostheses

As with removable prosthodontics, bilateral simultaneous contact is the most important prerequisite for an acceptable occlusion with fixed prosthodontics. Lateral excursive contact development for implant fixed prosthodontics will depend on the circumstances surrounding the construction of each occlusion.

When implants are used as adjunctive abutments, and the stresses of occlusion are well tolerated by the remaining natural dentition, the lateral disclusion factors should be on the natural teeth (Fig 9). If, however, the implants replace all or a large portion of the abutments, or if the remaining dentition cannot tolerate lateral occlusal forces, then anterior disclusion, usually over the canine areas, should be developed (Fig 10).

When cantilevers are used, the length of the cantilever should never be greater than 20 mm and is best kept under 15 mm.[2] The shorter lengths will minimize torque to the most posterior implant abutment. Eliminating prematurities in RCP and IP, reducing the size of the occlusal table, and reducing the number of occlusal contacts will also aid in reducing occlusal stresses. Force values on any cantilever are evaluated using the T-scan, and adjusted to the lowest level possible on each cantilevered segment (Fig 11).

Summary

Implant protheses require the same careful development of occlusion as do prostheses constructed for the natural dentition. However, the bone-implant interface or the prosthesis itself may not have the capacity to withstand forces developed either by deflective contacts in RCP or IP or heavy or hard forces inadvertently placed in certain areas of the occlusion.

The T-scan, a system that quantifies occlusal contact timing and force, accomplishes the following goals of implant prosthodontic occlusion:

1. Bilateral simultaneous contact at the time of insertion
2. Smooth, even working contacts with no interfering contacts in RCP or IP
3. Equality of force of the final contacts
4. Records of monitoring occlusal contacts over time for bilateral simultaneous contact and force distribution

References

1. Adell R, Lekholm U, Rockler B, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981;10:387.
2. Kirsch A, Mentag PJ: The IMZ endosseous two phase implant system: a complete oral rehabilitation. *J Oral Implantol* 1986;12:576.
3. Brånemark P-I, Zarb G, Albrektsson T: *Tissue-Integrated Prostheses*. Chicago, Quintessence Publ Co, 1987.
4. Haraldson T, Carlsson GE, Ingervall B: Functional state, bite force, and postural muscle activity in patients with osseointegrated oral implant bridges. *Acta Odontol Scand* 1979;37:195.
5. Williams WN, Levin AC, LaPointe LL, et al: Bite force discrimination by individuals with complete dentures. *J Prosthet Dent* 1985;54:146.
6. Lundgren D, Laurell L: Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. II. Unilateral posterior two-unit-cantilevers. *J Oral Rehabil* 1986;13:191.
7. Laurell L, Lundgren D: Interfering occlusal contacts and distribution of chewing and biting forces in dentitions with fixed cantilever prostheses. *J Prosthet Dent* 1987;58:626.
8. Beyron H: Optimal occlusion. *Dent Clin North Am* 1969;13:537.
9. Ramfjord SP, Ash MM: *Occlusion*, ed 2. Philadelphia, W. B. Saunders Co, 1971.
10. Dawson PE: *Evaluation, Diagnosis and Treatment of Occlusal Problems: A Textbook of Occlusion*. St Louis, CV Mosby Co, 1978.
11. Graf H, Zander HA: Tooth contacts in mastication. *J Prosthet Dent* 1963;13:1005.
12. Gibbs CH, Mahan PE, Lundeen HC, et al: Occlusal forces during chewing—influence of biting strength and food consistency. *J Prosthet Dent* 1981;46:561.
13. Gibbs CH, Mahan PE, Lundeen HC, et al: Occlusal forces during chewing and swallowing—measured by sound transmission. *J Prosthet Dent* 1981;46:443.
14. Dawson PE, Arcan M: Attaining harmonic occlusion through visualized strain analysis. *J Prosthet Dent* 1981;46:615.
15. Maness WL, Benjamin M, Podoloff R, et al: Computerized occlusal analysis: a new technology. *Quintessence Int* 1987;18:292.
16. Maness W, Chapman RJ, Dario LD: Laboratory evaluation of the direct reading digital occlusal sensor. *J Dent Res* 1985;43(special issue):308 (abstr No. 1199).
17. Podoloff R, Benjamin M: A tactile sensor for analyzing dental occlusion. *Sensors* 1989;6:41. □