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# Establishment of an Implant Selection Protocol for Predetermined Success

Abstract

Previously, implant selection was confined to radiographs and to plastic implant templates for evaluation of existing bone. The aim of this study was to determine implant support areas in a compressive mode and to establish a standard *via* an implant selection protocol. Successful implant selection, regardless of the device design, is relevant to a patient's muscular efficiency and implant support values based on bone quality and size of prescribed bridge. The compressive areas of support, in $mm^2$, of 15 implant designs were computer-analyzed and graph-evaluated. Major/minor diameters and the lengths of screws and cylindrical types of devices were calculated. In addition, the length, width, vents, and any lateral support areas of blade types were recorded. Average muscular force data, provided by clinical transducer studies, and literature reports of the mechanical properties of trabecular bone were correlated with computer bone analyses.

These studies determined the quality of maxillary and mandibular bone to be 10 MPa and 15 MPa, respectively. Results indicated that four-unit bridges, at 50 lbs of applied force, require an area 31.14 $mm^2$ of implant support in a compressive mode in the maxilla, and a support area of 20.76 $mm^2$ in the mandible. Five-unit bridges require 40.84 $mm^2$ in the maxilla and 27.23 $mm^2$ for the mandible, because of the moment force, or torque, on the implant.

Findings indicated that by determining: (1) the patient's muscular efficiency at implant sites (quantifying dynamic values of the forces and moments on implants supporting functioning bridges); (2) implant support values based on the compressive strength of the cancellous bone at implant sites; and (3) the size of the prescribed bridge, it is possible for the success (or failure) of a selected implant to be predetermined.

## Introduction

The treatment of edentulous patients has necessitated a 100% increase in the use of dental implants over the past two years (**Biomedical Business International**, 1988). Accordingly, the number of patients who may encounter an increase in failing cases may escalate. A need exists for a more predictable methodology for successful implant selection on a long-term basis.

Today, implant selection is most commonly accomplished by evaluation of panoramic and periapical radiographs (Linkow and Chercheve, 1970; Updegrave, 1966). These x-rays are compared with schematic representations of available implant designs by superimposition of a plastic template upon the radiograph so that the appropriate device size and configuration can be selected (Valen, 1983; Weiss, 1986). Although this method has proved to be successful for many cases, it does not allow for consideration of the patient's unique biodynamic and physiologic capabilities, nor does this method ensure that the chosen device has, by its design, sufficient support capacity for long-term efficiency when placed into function (Valen, 1990a).

When more scientific criteria are used for selection, it is possible to predict more accurately the longevity of a given implant within specific parameters. Presented here are some of the critical factors that influence this predetermination and, by so doing, contribute to the greater success of implants (Valen, 1990b).

TABLE 1

THIS STUDY, INVOLVING 15 IMPLANTS, REPRESENTS THE APPROXIMATE SURFACE SUPPORT AREAS, IN mm.[2] PROVIDED BY VARIOUS ENDOSTEAL DEVICES *IN A COMPRESSIVE MODE*, COMPARED WITH IMPLANT SUPPORT VALUES RELEVANT TO THE QUALITY OF AVAILABLE BONE FOR A GIVEN IMPLANT

# APPROXIMATE SUPPORT AREAS (mm2) IN THE BONE PROVIDED BY ENDOSTEAL IMPLANTS IN A COMPRESSIVE MODE

## BLADE IMPLANTS

| NAME | MESIO DISTAL LENGTH | HEAD | VENT | APEC | GROOVES | FLEXI-CUP | TOTAL SUPPORT AREA |
|---|---|---|---|---|---|---|---|
| Wedge Blades (Linkow) | 25mm | 2mm | 3.7mm | 1.0mm | ____ | ____ | 6.7mm |
| Improved Blades (Linkow-Weiss) | 25mm | 2mm | 4.2mm | 3.0mm | ____ | ____ | 9.2mm |
| Large plate implants | 30mm | 3mm | 15.0mm | 3.7mm | ____ | ____ | 21.7mm |
| *Flexi-cup (VALEN)* | *25mm* | *2mm* | *5.7mm* | *8.7mm* | *5.5mm* | *13.6mm* | *35.5mm* |
| Conventional Ramus Implant | | 4mm | 30.0mm | 2.0mm | ____ | ____ | 36.0mm |
| Improved Ramus Implant | | 6mm | 37.0mm | 4.0mm | ____ | ____ | 42.0mm |

## CYLINDER AND SCREW IMPLANTS

| NAMES | DIAMETERS (in mm²) | LENGTH | HEAD | VENT | APEX | THREADS | TOTAL SUPPORT AREA |
|---|---|---|---|---|---|---|---|
| Biotes | 5.5 | 16.0 | 0.3mm | 2.mm | 1.0mm | 10.mm | 13.3mm |
| Core-Vent | 5.5 | 16.0 | 0.5mm | 21.mm | 2.5mm | 1.mm | 25.0mm |
| Steri-Oss | 4.0 | 12.0 | 0.5mm | ____ | 1.5mm | 9.mm | 11.0mm |
| TPS Screw | 4.0 | 14.0 | ____ | ____ | 3.0mm | 15.mm | 18.0mm |
| DB 1000 | 4.0 | 14.0 | ____ | 23.mm | 2.0mm | ____ | 22.0mm |
| Star-Vent | 4.0 | 14.0 | ____ | ____ | 1.2mm | 12.mm | 13.5mm |
| LaminOss™ | 4.0 | 13.0 | ____ | ____ | 10.0mm | 40.mm | 50.0mm |
| Flexi-Root | 4.0 | 14.0 | ____ | ____ | 10.0mm | 10.mm | 20.0mm |
| Vent-Plant | 4.0 | 14.0 | 0.5mm | 3.mm | 3.0mm | 12.mm | 18.5mm |

TABLE 2

THESE CHARTS SHOW THE MECHANICAL PROPERTIES OF CANCELLOUS BONE IN THE MANDIBLE AND MAXILLA, AS DETERMINED BY COMPUTER ANALYSES (CONDUCTED BY GEORGE L. SCHULTZ LABORATORIES FOR ORTHOPAEDIC RESEARCH, NEWARK, NJ) OF PREVIOUSLY OBTAINED VALUES OF CANCELLOUS BONE FROM VARIOUS PARTS OF THE HUMAN BODY. THE RESULTS INDICATE THE MECHANICAL PROPERTIES, OR FRACTURE POINT, OF CANCELLOUS BONE TO BE 10 MPa FOR THE MAXILLA AND 15 MPa FOR THE MANDIBLE.

**STATIC COMPRESSIVE STRENGTH OF MAXILLARY CANCELLOUS BONE 10 MPa**

| APPLIED FORCE IN POUNDS | REQUIRED BONE AREA IN SQUARE MM |
|---|---|
| 1 | 0.444 |
| 5 | 2.220 |
| 10 | 4.450 |
| 15 | 6.670 |
| 20 | 8.900 |
| 25 | 11.120 |
| 30 | 13.350 |
| 35 | 15.570 |
| 40 | 17.790 |
| 45 | 20.020 |
| 50 | 22.240 |
| 55 | 24.470 |
| 60 | 26.690 |
| 65 | 28.910 |
| 70 | 31.140 |
| 75 | 33.360 |
| 80 | 35.590 |
| 85 | 37.810 |
| 90 | 40.040 |
| 95 | 42.260 |
| 100 | 44.480 |
| 105 | 46.710 |
| 110 | 48.930 |
| 115 | 51.160 |

**STATIC COMPRESSIVE STRENGTH OF MANDIBULAR CANCELLOUS BONE 15 MPa**

| APPLIED FORCE IN POUNDS | REQUIRED BONE AREA IN SQUARE MM |
|---|---|
| 1 | 0.296 |
| 5 | 1.480 |
| 10 | 2.970 |
| 15 | 4.450 |
| 20 | 5.930 |
| 25 | 7.410 |
| 30 | 8.900 |
| 35 | 10.380 |
| 40 | 11.860 |
| 45 | 13.350 |
| 50 | 14.830 |
| 55 | 16.310 |
| 60 | 17.790 |
| 65 | 19.280 |
| 70 | 20.760 |
| 75 | 22.240 |
| 80 | 23.720 |
| 85 | 25.210 |
| 90 | 26.690 |
| 95 | 28.170 |
| 100 | 29.660 |
| 105 | 31.140 |
| 110 | 32.620 |
| 115 | 34.100 |

## Methods

To establish a scientific methodology for successful selection of a dental implant, three factors were evaluated:

### *(1) Implant surface support area in a compressive mode*

So that numerical value could be assigned to the degree of bone support provided by given devices, 15 implants were computer-analyzed as to their overall surface area. This offered information with regard to their supportive resistance in bone when placed in a compressive mode. The study included seven screw-type devices, six blades, and two cylindrical implants (Table 1). (For a list of implant manufacturers, see the"Acknowledgments".)

### *(2) Quality of bone*

So that the density of bone could be evaluated, mechanical properties of cancellous bone were de-

TABLE 3

"THE AVERAGE OCCLUSAL FORCE GENERATED BY THE GNATHODYNAMIC MUSCULAR SYSTEM ON SPECIFIC TEETH. NOTE THAT LINEAR FORCES DECREASE WITH INCREASING DISTANCE FROM THE CONDYLE. THE MAGNITUDE OF AVERAGE FORCES VARIES BY A FACTOR OF NINE FROM THE POSTERIOR (216.1 LBS) TO THE ANTERIOR (22.89 LBS)". (KNOBLAUCH, 1971)

**MAXIMUM HUMAN BITING FORCES IN POUNDS (ON CENTRALS, BICUSPIDS, MOLARS)**

| ORAL READING | TOOTH #31 | TOOTH #30 | TOOTH #29 | TOOTH #28 | TOOTH #25/24 | TOOTH 21 | TOOTH #20 | TOOTH #19 | TOOTH #18 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 197. | 182. | 75. | 50. | 35. | 60. | 97. | 197. | 197. |
| 2 | 182. | 165. | 67. | 47. | 25. | 61. | 85. | 213. | 207. |
| 3 | 230. | 206. | 123. | 90. | 65. | 100. | 150. | 177. | 182. |
| 4 | 215. | 210. | 184. | 85. | 47. | 117. | 160. | 198. | 203. |
| 5 | 222.5 | 190. | 112.5 | 92.5 | 42.5 | 90. | 117.5 | 201. | 222.5 |
| 6 | 215. | 179. | 105. | 83. | 46.5 | 91.5 | 109. | 187.5 | 222.5 |
| 7 | 237.5 | 200. | 121.5 | 90. | 49. | 94. | 135. | 212.5 | 237.5 |
| 8 | 230. | 207.5 | 125. | 92.5 | 46. | 100. | 137.5 | 217.5 | 242.5 |
| Â | 1729. | 1539.5 | 913. | 630. | 356. | 713.5 | 991. | 1603.5 | 1724. |
| **Average** | **216.1** | **192.4** | **114.1** | **78.75** | **44.5** | **89.2** | **123.9** | **200.3** | **215.4** |
| Standard Deviation | ±6.14 | ±5.29 | ±11.84 | ±6.29 | ±3.81 | ±6.48 | ±8.65 | ±4.55 | ±6.17 |

termined by all values of cancellous bone previously obtained from all body areas (Hastings and Ducheyne, 1984) being taken and, through computer analyses, the values for both the mandible and the maxilla being set (Table 2).

### *(3) Muscular efficiency*

For quantification of applied forces for a given patient, maximum biting force was determined by performance of transducer studies on a patient. The data obtained were then correlated with previous studies made by various investigators (Brunski and Hipp, 1984; Knoblauch, 1971; Mansour, 1972).

Since maximum biting forces are an important factor in these determinations, Knoblauch's study (1971) was utilized to obtain results (Table 3).

## Results

By simplification, the mandible functions as a Class III lever (Gabel, 1961), which has a mechanical advantage less than one. However, from the first molar to the condyle, when natural abutments are splinted to implants, the mandible functions as a Class II lever. Therefore, the force on the implant is multiplied by the length of the moment arm. By definition, a Class II lever is one in which the resistance force (implant in bone) lies between the applied force (elevator muscles) and the fulcrum point (condyle), and has a mechanical advantage greater than one (Valen, 1990b).

When the hypothetical implant prosthesis (Fig.) is analyzed from a biophysical point of view, the distance from Point A to Point B is termed the "moment arm" (classic cantilever), and is measured in inches. This is represented on the drawing by the letter "I". The total muscular force applied to the prosthesis (100 lbs directly over the implant) is represented by the letter "F". When multiplied, the resultant is known as the "moment torque". In this example, the moment torque is 200 pounds (2 inches $\times$ 100 lbs), and is represented by $\Gamma$ (gamma) in the formula.

## Discussion

Implants do not occupy a physiologic role. They possess certain supportive areas in the bone in order to maintain a bridge, under dynamic function, on a long-term basis simply by their design.

Based on data obtained from the three factors (Tables 1, 2, 3), the requirements of various four- and five-unit fixed bridges were calculated theo-

TABLE 4

*NOTE THAT AN APPLIED FORCE OF 50 LBS ON A FOUR-UNIT BRIDGE INCREASES (OR IS MULTIPLIED) TO 70 LBS AS A RESULTANT FORCE. THIS IS AN INCREASE IN THE DYNAMIC MAGNITUDE OF FORCE OF 40% DUE TO THE MOMENT ARM EFFECT OF THE FOUR–UNIT BRIDGE.

**AREA OF METAL-TO-BONE SUPPORT (mm²)REQUIRED FROM AN IMPLANT (IN A DYNAMIC MODE) FOR HYPOTHETICAL FOUR AND FIVE UNIT BRIDGES**

## FOUR UNIT BRIDGE

| PATIENT'S APPLIED STATIC FORCE | X | CANTILEVER LENGTH MOMENT ARM | = | RESULTANT DYNAMIC T/ FORCE | REQUIRED IMPLANT SURFACE AREA (MAXILLA) | REQUIRED IMPLANT SURFACE AREA (MANDIBLE) |
|---|---|---|---|---|---|---|
| (lbs.) | x | (inches) | = | (lbs. in.) | (mm²) | (mm²) |
| 5 | x | 1.4 | = | 7 | 3.10 | 2.07 |
| 10 | x | 1.4 | = | 14 | 6.21 | 4.14 |
| 15 | x | 1.4 | = | 21 | 9.34 | 6.22 |
| 20 | x | 1.4 | = | 28 | 12.45 | 8.30 |
| 25 | x | 1.4 | = | 35 | 15.57 | 10.38 |
| 30 | x | 1.4 | = | 42 | 18.67 | 12.43 |
| 35 | x | 1.4 | = | 49 | 21.75 | 14.50 |
| 40 | x | 1.4 | = | 56 | 24.91 | 16.57 |
| 45 | x | 1.4 | = | 63 | 27.97 | 18.64 |
| 50 | x | 1.4 | = | 70 | 31.14 | 20.76* |

TABLE 5

**NOTE THAT THE RESULTANT FORCE IS INCREASED FROM 50 LBS TO 92 LBS SIMPLY BY ADDITION OF A SECOND MOLAR TO THE SAME BRIDGE. THE CHANGE IN THE DYNAMIC MAGNITUDE OF FORCE IS NOW 85%, DUE TO THE SLIGHTLY LONGER MOMENT ARM.

**AREA OF METAL-TO-BONE SUPPORT (mm²)REQUIRED FROM AN IMPLANT (IN A DYNAMIC MODE) FOR HYPOTHETICAL FOUR AND FIVE UNIT BRIDGES**

## FIVE UNIT BRIDGE

| PATIENT'S APPLIED STATIC FORCE | X | CANTILEVER LENGTH MOMENT ARM | = | RESULTANT DYNAMIC T/ FORCE | REQUIRED IMPLANT SURFACE AREA (MAXILLA) | REQUIRED IMPLANT SURFACE AREA (MANDIBLE) |
|---|---|---|---|---|---|---|
| (lbs.) | x | (inches) | = | (lbs. in.) | (mm²) | (mm²) |
| 5 | X | 1.84 | = | 9.2 | 4.08 | 2.72 |
| 10 | X | 1.84 | = | 18.4 | 8.16 | 5.44 |
| 15 | X | 1.84 | = | 27.6 | 12.25 | 8.16 |
| 20 | X | 1.84 | = | 36.8 | 16.33 | 10.89 |
| 25 | X | 1.84 | = | 46.0 | 20.42 | 13.61 |
| 30 | X | 1.84 | = | 55.2 | 24.50 | 16.33 |
| 35 | X | 1.84 | = | 64.4 | 28.59 | 19.06 |
| 40 | X | 1.84 | = | 73.6 | 32.67 | 21.78 |
| 45 | X | 1.84 | = | 82.8 | 36.76 | 24.50 |
| 50 | X | 1.84 | = | 92.0 | 40.84 | 27.23** |

retically so that the appropriate implant for a given case in dynamic function could be determined (Tables 4 and 5).

### Conclusion

A more scientific method for dental implant selection has been established based on determination of the patient's muscular efficiency at the implant site, predetermined implant support values in a compressive mode (based on the mechanical properties of cancellous bone for the maxilla and mandible), and size of the prescribed bridge.

Implant selection should be based upon an evaluation of the potential magnitude of momenr torque (relative to the length of bridge prescribed) in each case. This concept is used so that a more accurate prognosis can be established for a selected implant.

Horizontal support planes, in the form of bone-to-implant interface in a compressive mode, were calculated as to the quantitative support of any given device required to sustain it successfully in the presence of the occlusal forces of a patient. Once an occlusal force registration is taken from the patient by means of transducer instrumentation, and such information is correlated with the mechanical properties of bone and length of prescribed bridge, an implant with appropriate support values may be selected which will be most likely to remain in a state of equilibrium on a long-term functional basis.

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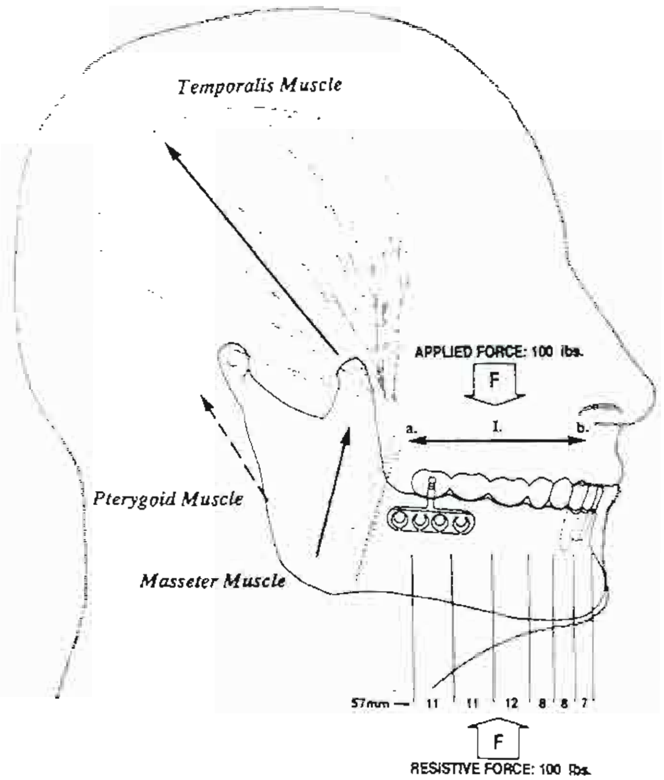


Figure. Schematic illustration representing a hypothetical bridge in dynamic function. This physiologic state can be expressed mathematically as follows: $\Gamma = F\,I$ (lb.in.), where F = Applied Force, I = Moment Arm, and Gamma = Potential Moment Torque. Implant selection should be realistically based on evaluation of potential moment torque in the bone for each individual clinical case, sinee the quality of bone for each patient is not constant. One must consider a "safety factor" in making an implant selection by choosing an implant with greater support values for long-term stability.

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