Tibial versus iliac bone grafts: a comparative examination in 15 freshly preserved adult cadavers

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Abstract
Purpose: We compared autogenous bone grafts from the proximal tibia and the anterior iliac crest under standardized conditions with regard to the attainable bone amount and the histological bone density.

Material and methods: In 15 freshly preserved adult cadavers, a corticocancellous block graft from the anterior iliac crest and a purely cancellous transplant from the tibia of the homolateral side were harvested respectively, with the length of the skin incision set at 6 cm for the iliac and at 3.5 cm for the tibial approach. The size of the iliac graft was defined to be between 1/3 and 1/4 of the total iliac length. At the medial tibia the maximum possible amount of cancellous bone was collected after preparation of a cortical lid. For volume determination grafts were cautiously cut up and then put in a water-filled measuring cylinder. In addition, bone density was measured by histomorphometry. The received data were statistically evaluated using the t-test for related samples at \( P = 0.05 \) and Pearson’s correlation analysis.

Results: From both donor sites approximately equal amounts of bone were available. This result is neither dependent on age nor on gender. In contrast, bone density turned out significantly higher in the iliac graft, with the difference showing a significant age dependence \( (r = -0.556) \).

Conclusions: Provided that no cortical transplants are needed, cancellous tibial bone grafts offer an appropriate alternative to the classic iliac bone graft, especially in elderly patients.

Bone deficit and bony defects are frequent conditions in the maxillofacial region. To replace the missing hard tissue bone grafting is often necessary with the amount of bone needed being dependent on the size and the geometry of the defect [Boyne & Herford 2001; Herford et al. 2003]. Cysts, traumatic bone loss and congenital bony defects, such as alveolar clefts, as well as bony defects subsequent to tumor resection are major indications for bone transplantation [Foitzik & Vietor 1996; Besly & Ward Booth 1999; Aboul-Hosn et al. 2006]. However, in the recent years grafting techniques which provide the atrophic edentulous posterior maxilla with an adequate bone stock for osseointegrated implants are gaining more and more importance. In particular, the sinus floor elevation, as first described by Tatum at the implant meeting held in Birmingham, Alabama, in 1976 and published subsequently by Boyne & James [1980], has become an undisputed standard pre-implantology procedure for the maxilla [Boyne & James 1980; Tatum 1986].
Countless grafting materials have been developed and utilized, but in spite of the continuous progress of bone-substitute technologies the autogenous bone graft is currently still considered the gold standard [Mendicino et al. 1996; Jensen et al. 1998; Lundgren et al. 1999; Jakse et al. 2001; Allegrini et al. 2003; Tiwana et al. 2006] due to its superior properties with regard to osteoinductivity, osteoconductivity and immunogenecity [Moy et al. 1993; Triplett & Schow 1996; Serra E Silva et al. 2006]. Especially, autogenous spongiosa is attributed to be of high biological value [Jensen et al. 1990; Tidwell et al. 1992; Jensen et al. 1998; Jakse et al. 2001].

Undoubtedly, the ilium is the most widely used extraoral donor site for autogenous bone grafts [Herford et al. 2003; Tiwana et al. 2006]. Nevertheless, the proximal tibia is likewise a reliable bone graft donor site [O’Keeffe et al. 1991], and is becoming more popular also for maxillofacial bone defects in the more recent past [Catone et al. 1992; Besly & Ward Booth 1999; Jakse et al. 2001; Lee 2003; Aboulhosn et al. 2006; Thor et al. 2006; Tiwana et al. 2006]. It offers some distinct advantages. First, the surgical procedure is relatively simple and can be performed under local anaesthesia. In addition, a sufficient amount of cancellous bone can be harvested with only minimal morbidity [O’Keeffe et al. 1991; Besly & Ward Booth 1999; Jakse et al. 2001; Herford et al. 2003]. However, the cortical bone available from this donor site is essentially limited to the access window.

In our current study, bone harvesting from the proximal medial tibia using the bone lid method according to Jakse [Jakse et al. 2001] [Fig. 1] was systematically compared to the anterior iliac crest donor site with regard to the attainable bone amount and histological bone density.

Material and methods

Patients

Fifteen freshly preserved human cadavers, nine male and six female, with their age ranging from 51 to 94 years (mean 76.8 years) were recruited into this study. In all cadavers a corticocancellous block graft from the anterior iliac crest and a purely cancellous transplant from the tibia of the homolateral side were harvested respectively under standardized conditions.

Surgical procedure and harvesting of the bone grafts

The harvesting procedure at the iliac crest was performed as follows [Fig. 2]: Starting with a skin incision set at a length of 6 cm and running in direction of the tension lines 3–4 cm cranially to the anterior superior iliac spine, the abdominal muscles were divided by sharp dissection, then the iliac crest and the inner surface of the iliac ala were carefully exposed [Fig. 2a]. Subsequent to completion of the osteotomy [Fig. 2b] to the desired size being one quarter to one third of the total iliac length, a corticocancellous block graft was removed with preservation of the outer cortical layer and further cancellous bone was collected from the adjacent marrow space using appropriately sized Volkmann’s spoons. On balance, the harvesting trauma was reduced to a justifiable extent by refraining from a large approach, excessive dissection of the soft tissue and thus the maximum possible bone removal which would be inextricably linked with long immobilization and comparatively much discomfort when treating “real” patients.

At the tibia [Fig. 3], the important anatomic landmarks such as the articular cavity, the tibial tuberosity and the medial tibial margin were first identified and highlighted [Fig. 3a]. An incision line of about 3.5 cm was drawn from craniomedially to caudolaterally according to the oblique fibers of the pes anserinus with the proximal limit 2 cm below the articular cavity. After the pes anserinus had been exposed by sharp and blunt dissection, a cortical lid with a size of 1.8 × 1.5 cm was prepared as proposed by [Jakse et al. 2001]. For that, first incisions were performed through the pes anserinus corresponding to the design of the planned bone lid whose cranial and caudal sides should run parallel and whose lateral side should run perpendicular to the fibers of the pes anserinus [Fig. 3b]. Medially, the pes remained untouched; thus the cortical lid prepared by using a micro bone saw and different chisels remained retained at its medial base [Fig. 3c]. Then, the maximum possible amount of cancellous bone was gathered with suitable spoon excavators.

Determination of volume and histomorphometric analysis

For determination of their respective volumes the grafts were cautiously cut up by a bone saw and / or a Luer’s bone rongeur, the bone pieces were put in a 1 ml calibrated 250 ml measuring cylinder filled with 50 ml water. The respective bone volume equaled the measured total volume minus 50 ml. In order to perform a histomorphometric evaluation of the bone,
Histological sections were prepared from each bone graft by the sawing and grinding technique according to Donath (Donath & Breuner 1982), and subsequently were stained with Giemsa in the customary manner. Bone density defined as the percentage proportion of mineralized tissue to the entire tissue was estimated using a computer-based histomorphometric analysis system comprising a Zeiss light microscope (model diaplan, Carl Zeiss MicroImaging GmbH, Göttingen, Germany) connected with a personal computer via charged coupled device camera, and the analysis software Leica QWin (Leica Mikrosysteme Vertriebs GmbH, Bensheim, Germany). With the camera’s live image being displayed on the PC screen, the sections of each graft were first surveyed at a magnification of ×40 to obtain an overview about the different compartments of each slide. While scrutinizing the sections at a magnification of ×160 the area of mineralized tissue within the measuring frame of 229456.7 μm² determined by the software was measured in 50 visual fields. For this purpose all bony structures within the frame were outlined with the mouse cursor whereupon the included area was colored, calculated and added-up automatically by the software (Fig. 4). Subsequently, the sum of all measured areas was put in proportion to the overall area of the 50 measuring frames and thus, bone density was determined.

Statistical analysis
In addition to an explorative data analysis, a t-test for related samples was performed to statistically compare the measured graft volumes as well as the ascertained values for bone density. The influence of gender on the results was examined by means of an unpaired t-test. Values of $P<0.05$ were considered significant. For assessment of age-dependence Pearson’s correlation analysis was done. Statistical computations were performed using the Statistical Package for Social Sciences (SPSS), version 14, under Windows XP.

Results
Graft volume and histomorphometric analysis
On the whole, both donor sites, the iliac and the tibial one, provide at least satisfactory amounts of autogenous bone and show acceptable results in regard to the bone density of the corresponding transplants (Table 1).

The mean graft volume presents marginally higher values for the tibial donor site, however the difference compared with the iliac graft is not statistically significant (Fig. 5) and in accordance to the 95% confidence interval for the difference in mean values, both donor sites must be assumed equal regarding the attainable bone amount (Table 2). This result is neither dependent on gender nor on age as it could be revealed by means of an unpaired t-test and Pearson’s correlation analysis for the differences of the respective values for both types of transplant. In contrast, the histomorphometrically determined bone density turned out significantly higher in the iliac graft showing a mean density of 22.3% in comparison to 16.7% for the tibial transplant (Fig. 6). This difference in bone density is significantly dependent on age ($r = -0.556$; Fig. 7), whereas a gender-dependence could be statistically ruled out ($P = 0.09$). Consequently, with advanced age the different bone densities of both grafts lose relevance.
Further statistical analyses

If, in a further step, both donor sites are considered separately from each other, the iliac crest of the male cadavers provides markedly higher graft volumes as well as bone densities when compared with the female cadavers (Table 3). Overall, the iliac graft volumes prove to be relatively constant in the observed age interval ($r = 0.4$), whereas the bone density suggests a tendency towards age-dependence (Fig. 8). In contrast to the above findings, the tibial transplant shows neither age nor gender dependence in regard to the examined parameters (Table 4).

In summary, both donor sites provide comparably good results regarding the graft volume whereas the iliac crest is distinctly superior concerning the bone density of the corresponding transplants.

Discussion

The primary purpose of this investigation was to scientifically examine the tibial in comparison to the iliac donor site regarding attainable graft amount and histological bone density. Numerous studies have discussed the properties of either iliac or tibial grafts [Kraut & Judy 1993; Lindberg et al. 1996; Caminiti et al. 1999; Lee 2003; Aboul-Hosn et al. 2006; Tiwana et al. 2006], but literature is lacking in examinations with an intraindividual comparison of these two donor sites. As second important issue the characteristics of both grafts themselves were systematically analyzed in regard to age-dependence and sex specificity.

What is important we wanted to examine the possible bone graft amounts under practically relevant and realistic conditions. Of course it would have been theoretically possible to choose a larger approach at the iliac crest and to harvest a maximum sized bone block. However, most of the patients undergoing a bone transplantation in the maxillofacial region attach importance to rapid mobilization, a short hospital stay and tolerable pain. Major complications as fractures in the harvesting area, a permanent sensory disturbance or remaining gait problems should be avoided. Therefore we decided on the described harvesting method which we, in our experience, can also expect of our ‘real’ patients.

In general, there is a relatively low but significant morbidity associated with the iliac crest donor site. Younger & Chapman (1989) reported a rate of major complications of 9.2%, whereas minor complications were observed in 20.7% of the examined cases. Sensibility impairment of the lateral femoral cutaneous nerve (LFCN)
Table 2. Statistical comparison between both donor sites

<table>
<thead>
<tr>
<th>Donor site</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>t-Test</th>
<th>P-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graft volume</td>
<td>Iliac crest</td>
<td>9.15 ml</td>
<td>2.7</td>
<td>0.095</td>
<td>[3.18; 0.289]</td>
</tr>
<tr>
<td></td>
<td>Tibia</td>
<td>10.6 ml</td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone density</td>
<td>Iliac crest</td>
<td>22.3 %</td>
<td>12.5</td>
<td>0.042</td>
<td>[0.23; 10.92]</td>
</tr>
<tr>
<td></td>
<td>Tibia</td>
<td>16.7 %</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Dependence on gender in the iliac graft

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>t-test</th>
<th>P-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graft volume</td>
<td>Male</td>
<td>10.4 ml</td>
<td>2.7</td>
<td>0.029</td>
<td>[0.36; 5.71]</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>7.3 ml</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone density</td>
<td>Male</td>
<td>27.6 %</td>
<td>12.3</td>
<td>0.04</td>
<td>[0.69; 25.64]</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>14.4 %</td>
<td>8.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Dependence on gender in the tibial graft

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>t-test</th>
<th>P-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graft volume</td>
<td>Male</td>
<td>11.6 ml</td>
<td>2.1</td>
<td>0.123</td>
<td>[−0.78; 5.83]</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>9.1 ml</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone density</td>
<td>Male</td>
<td>18.54 %</td>
<td>6.2</td>
<td>0.135</td>
<td>[−1.62; 10.71]</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>14.0 %</td>
<td>3.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6. Comparative presentation of bone density (in percent) arisen for the iliac and for the tibial grafts.

Fig. 7. Relationship between the bone density difference and patients’ age revealing a significant correlation ($r = −0.316$).

Geressen et al. Tibial versus iliac bone grafts

is described in <1% of the patients [Mendicino et al. 1996]. In an own retrospective study of 319 patients with non-vascularized grafts from the iliac crest [unpublished observations], we were able to reveal, that sensory disturbances in the dermatom of LFCN as well as postoperative pain are significantly dependent on the bone amount harvested. Therefore a less invasive harvesting procedure should reduce the discomfort to the patient. However, the proximal tibia as donor site excels by its comparatively even lower morbidity. The overall complication rates reported for this procedure range from 1.3% to approximately 4% [O’Keeffe et al. 1991; Lee 2003]. Major complications as fracture of the proximal tibia are extremely rare [Thor et al. 2006].

When considering the bone amounts, it is notable that in particular for the tibial donor site, the graft volumes turn out lower as reported in the literature. These values vary between 20 and 40 ml for tibial grafts and between 7 and 40 ml for transplants from anterior iliac crest [Kraut & Judy 1993; Foitzik & Vietor 1996; Herford et al. 2003; Aboul-Hosn et al. 2006; Tiwana et al. 2006]. In the study in hand, the transplants from the proximal tibia show on average 10.6 ml [range 5–16 ml, Table 1] bone amount, a markedly smaller volume. In the iliac crest, for which a mean graft volume of 9.15 ml [range 6–14 ml] was measured, the difference to reported values is less obvious. A possible reason for the comparatively small volumes in our collective could be older age of the cadavers (76.8 years), but on the other hand neither the graft volumes for the tibial ($r = 0.06$) nor for the iliac grafts ($r = 0.42$) exhibit age dependence in the examined age interval. Furthermore, our applied measuring method consisting of volume displacement of water could play an important role, since, in contrast to the simple determination of volume by a syringe or a measuring jug [Lindberg et al. 1996], the hollow spaces between the bone pieces do not affect the measured volume. Nonetheless, bone amount obtained from each donor site is sufficient to perform sinus lifting, one of the most important indications for harvesting autogenous bone grafts, at least unilaterally (Lee 2003).

Due to the significantly higher bone density and bone volume comparable to the tibial transplants, grafts from the iliac crest may have a better osteoinductive and osteoconductive potential as they provide a higher amount of osteoinductive and osteoconductive material in the recipient site. However, the bone density difference disappears with age, so that especially in older patients both graft types should lead to comparably acceptable treatment results.

An influence of gender was only found for the iliac graft. The acquired data indicate that in men larger grafts with
higher bone density can be harvested. Thus, hormonal as well as constitutional factors seem to be more relevant to the iliac crest than to the tibia.

In conclusion, for indications not requiring cortical bone transplants cancellous grafts from proximal tibia represent a real alternative to the widely spread iliac bone graft, particularly in elderly patients and irrespective of gender.

References


Gerressen et al. Tibial versus iliac bone grafts


