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Original article

Dimensional analysis of total hip arthroplasty polyethylenes☆

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ABSTRACT

Objective: This paper performs a dimensional analysis of different total hip arthroplasty polyethylenes, cemented and non-cemented, Brazilian made and imported.
Methods: It was considered acetabular components with 50 mm for the 28 mm femoral heads. Dimensional analysis was performed on a 3D coordinate Carl-Zeiss robotic device. Polyethylene thickness and its external measurements (maximum diameter and diameter for the femoral head) were measured.
Results: The minimum thickness of the polyethylene was guaranteed on all tested components. The thickness of cemented acetabular varied from 19.185 mm to 25.358 mm, while the thickness of the non-cemented acetabular varied from 12.451 mm to 19.232 mm. The thickness was 27.96% lower in non-cemented acetabular components. With respect to the polyethylene acetabular cavity that receives the femoral head, all internal diameters exhibit at least 28 mm. In relation to the maximum outer diameter of the polyethylene, only one cemented acetabular component reached 50 mm in diameter.
Conclusions: There are large differences in measurements between brands and models analyzed. Cementless acetabular components have the smaller thickness. The diameters of non-cemented acetabular were also lower than those cemented at the expense of their need to insert into the metal-back.

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Análise dimensional de diferentes acetábulos usados na artroplastia total do quadril

RESUMO

Objetivo: O presente estudo faz uma análise dimensional dos diferentes acetábulos cimentados e não cimentados, nacionais e importados, disponíveis no mercado nacional para artroplastia total do quadril.

Métodos: Foram considerados os acetábulos de 50 mm, destinados às cabeças femorais de 28 mm. As análises dimensionais foram feitas em um equipamento tridimensional robótico de medição por coordenadas. Avaliou-se a menor espessura do polietileno e suas medidas externas (diâmetro do espaço para a cabeça femoral e diâmetro máximo do acetábulo).

Resultados: A espessura mínima do polietileno foi garantida em todos os componentes testados. A espessura dos acetábulos cimentados variou de 19,185 mm a 25,358 mm, enquanto a espessura dos acetábulos não cimentados variou de 12,451 mm a 19,232 mm A espessura foi em média 27,96% menor nos acetábulos não cimentados. Em relação à cavidade acetabular do polietileno que recebe a cabeça femoral, todos os diâmetros internos apresentaram pelo menos 28 mm. Em relação ao diâmetro externo máximo do polietileno, apenas um acetábulo cimentado atingiu os 50 mm de diâmetro.

Conclusões: Observaram-se grandes diferenças nas medidas entre as marcas e os modelos analisados. Os acetábulos não cimentados têm uma espessura menor. Os diâmetros dos acetábulos não cimentados também foram menores do que os cimentados, à custa de sua necessidade de inserção no *metal-back*.

Palavras-chave:
Artroplastia de quadril
Acetábulo
Polietileno

Introduction

Hip surgery continues to face constant challenges due to the growing volume of patients and increasing costs, and because of controversies regarding the reliability and performance of the implants.[1,2] Total hip arthroplasty has been increasingly indicated for younger and more active patients. The results from hip arthroplasty have been shown to be excellent among more elderly patients. However, among younger patients (<40 years), the failure rate over a five-year period is between 21% and 28%.[3–7] The classical combination of metal articulated with ultra-high molecular weight polyethylene continues to be the most widely used type,[1] and it will continue to be so for many years to come, with the advent of crosslinked polyethylene.

The metal–polyethylene surface is inexpensive and enables immediate weight-bearing. Moreover, surgeons have wide experience with this method and the present-day acetabula. However, this method has the disadvantage that the cement ages and progressively disintegrates. Schulte et al.,[8] Keener et al.,[9] Callaghan et al.[10] and Buckwalter et al.[11] found that 69–90% of their results using Charnley prostheses were good, with 20–30 years of follow-up. Wroblewski et al.[12] reported an even longer follow-up period (30–40 years) for Charnley prostheses, with 90% good results.

Wearing out is the greatest obstacle to longevity among polyethylene prostheses. Young and active patients, particularly males under the age of 55 years, are the ones who present the greatest risk of accelerated wear.[1] The thickness of the polyethylene has been reported to be one of the factors that cause wear. According to Bartel et al.,[13] the stresses in the polyethylene become greater if its thickness is less than 5 mm, which leads to an unacceptable risk of premature wear. Therefore this critical thickness should be foreseen in order to avoid intense wear. For this reason, precise size assessment needs to be done at the time of manufacturing the implants. The aim of the present study was to make an analysis on the dimensions of different cemented and non-cemented 50 mm acetabula that are made in Brazil or imported.

Materials and methods

The present study made a dimensional assessment on acetabula that are available on the Brazilian market, involving 11 Brazilian and imported components of a wide variety of brands and models (both cemented and non-cemented types). These were then named according to their manufacturers as A, B, C, etc., for ethical and legal reasons. In order to standardize this study, only 50 mm acetabula destined for 28 mm femoral heads were taken into consideration.

All the acetabula were measured at the Physical Metallurgy Laboratory of the Federal University of Rio Grande do Sul (Lamef/UFRGS). This laboratory is accredited by the National Institute of Metrology, Quality and Technology (Inmetro) and does analyses for the National Health Standards Surveillance Agency (Anvisa). The dimensional analyses were performed on a three-dimensional robotic coordinate measurement device (Carl Zeiss, Vista model) (Fig. 1). The minimum polyethylene thickness in each specimen was measured in this manner. In this regard, it needs to be borne in mind that the polyethylene pieces present grooves and flanges that do not represent its real thickness measurement. For this reason, a 3D system for locating the point of least thickness was needed. Each acetabulum was analyzed individually. The

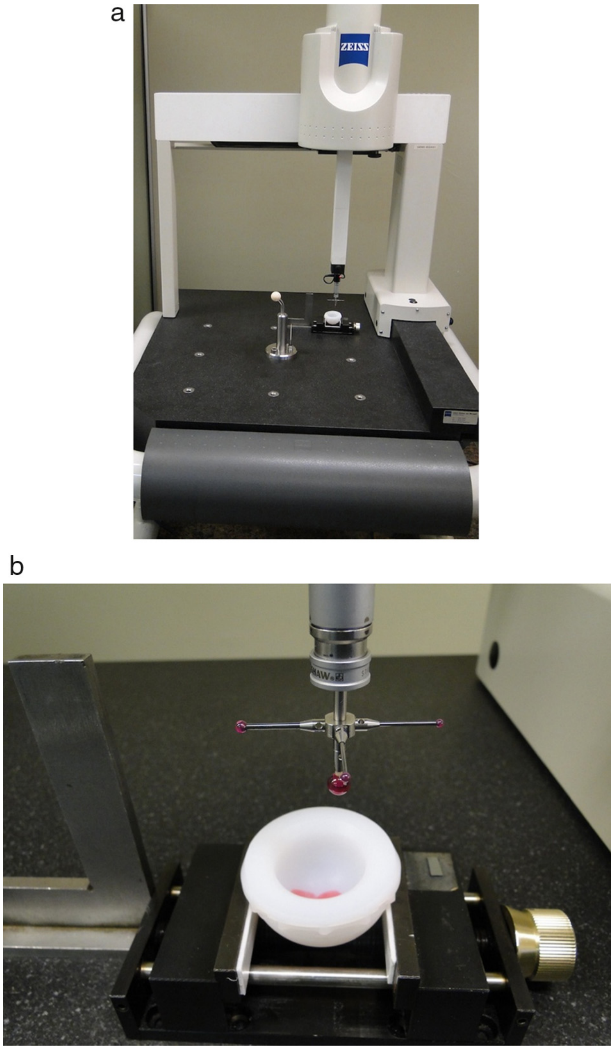

Fig. 1 – Carl Zeiss device used for making the measurements: (a) in general view and (b) focused.

external measurements obtained (diameter of the space for the femoral head and the maximum overall diameter of the acetabulum) were then compared with measurements made by precision pachymeters, taking the mean of three measurements.

Results

Table 1 presents the results obtained for the different manufacturers in relation to the cemented and non-cemented components. The minimum thickness of the polyethylene was assured in all the components tested. However, taking into consideration the different acetabula, large variations were observed. The thickness of the Brazilian cemented acetabula ranged from 19.185 mm to 25.358 mm (mean of 22.593 mm), while the thickness of the imported cemented acetabula ranged from 21.058 mm to 23.143 mm (mean of 22.053 mm). The thickness of the Brazilian non-cemented acetabula ranged from 15.444 mm to 19.232 mm (mean of 17.338 mm), while the thickness of the imported non-cemented acetabula

Table 1 – Measurements on the different acetabula.

	Thickness (mm)	Internal diameter (mm)	External diameter (mm)
Brazilian cemented acetabula			
A	23.236	28.1899	50.0321
A	19.185	28.2313	49.6687
B	25.358	28.2668	49.8918
Mean	22.593	28.2293	49.8642
Deviation	3.1363	0.0385	0.1833
Brazilian non-cemented acetabula			
A	19.232	28.1200	45.3300
C	15.444	28.2836	47.9197
Mean	17.338	28.2018	46.62485
Deviation	2.6785	0.1157	1.8312
Imported cemented acetabula			
D	21.959	28.1114	49.5826
E	23.143	28.2846	49.7334
F	21.058	28.4393	47.7133
Mean	22.053	28.278	49.010
Deviation	1.0457	0.1640	1.1253
Imported non-cemented acetabula			
D	14.356	28.1689	43.1000
E	18.929	28.1775	45.7739
F	12.451	28.0620	45.9389
Mean	15.245	28.136	44.938
Deviation	3.3293	0.0643	1.5935

ranged from 12.451 mm to 18.929 mm (mean of 15.245 mm). Taking all the acetabula into consideration, the mean thickness of the cemented acetabula was 22.323 mm, while the thickness of the non-cemented acetabula was 16.082 mm. Thus, the thickness of the non-cemented acetabula was on average 27.96% less.

In relation to the polyethylene acetabular cavity that receives the femoral head, all the internal diameters were at least 28 mm. The closest-fitting cavity was in an imported non-cemented prosthesis (28.062 mm), while the one with the greatest play was an imported cemented acetabulum (28.439 mm).

In relation to the maximum external diameter of the polyethylene, only one Brazilian cemented acetabulum reached a diameter of 50 mm (50.032 mm), and the diameters went down to as small as 43.100 mm, which was found in an imported non-cemented prosthesis. The diameters of the Brazilian cemented acetabula ranged from 49.668 mm to 50.032 mm (mean of 49.864 mm), while the imported cemented acetabula ranged from 47.713 mm to 49.733 mm (mean of 49.010 mm). The diameters of the Brazilian non-cemented acetabula ranged from 45.330 mm to 47.919 mm (mean of 46.624 mm), while the imported non-cemented acetabula ranged from 43.100 to 45.938 mm (mean of 44.938 mm).

Discussion

Huo et al.[2] reported that the rates of wear for crosslinked polyethylene found for heads of 28 mm and 32 mm did not differ, and that this was important because larger heads have been used to improve the clinical performance of implants and reduce the risk of dislocation. Despite the clear differences in the dimensions determined for the pieces, it has to be taken into account that not all the polyethylene pieces are manufactured with crosslinking and, even if they were, different degrees of radiation might introduce different resistances. However this factor was not evaluated in the present study. The aim here was to evaluate the dimensional characteristics as a means of assessing the compatibility of these elements.

Bartel et al.[13] showed that a minimum thickness of 5 mm was necessary in order to avoid excessive wear. We attempted to establish this affirmation in the present study and found that all the acetabula had measurements greater than this value. Charnley, in his first studies, concluded that the wear on conventional acetabula was 0.1 mm/year. Glyn-Jones et al.[14] analyzed the wear on the polyethylene in 54 total prostheses and observed that crosslinked polyethylene wore down at 0.06 mm/year, while finding the same value as seen by Charnley in conventional acetabula. McCalden et al.[15] observed even smaller values in a randomized prospective study comparing conventional and crosslinked polyethylene pieces: 0.05 mm/year and 0.003 mm/year, respectively. Similar results were reported by Thomas et al.[16]: 0.005 mm/year for crosslinked polyethylene and 0.037 for conventional polyethylene. Woolson and Murphy[17] and Gaffey et al.[18] evaluated patients with Harris–Galante prostheses and observed wear of 0.14–0.15 mm/year. Stilling et al.,[19] Kampa et al.,[20] Mutimer et al.,[21] Datir and Angus[22] and Emms et al.[23] evaluated non-cemented prostheses and concluded that the wear on the polyethylene ranged from 0.12 to 0.28 mm/year. Witte et al.[24] evaluated the Spotorno prosthesis and observed 0.31 mm/year. More recently, Kurtz et al.[25] conducted a systematic review on the literature and concluded that crosslinked polyethylene presented mean wear of 0.042 mm/year and conventional polyethylene 0.137 mm/year. Caton and Prudhon[26] recently conducted a review on Charnley prostheses over a long follow-up period and came to the same conclusion as already demonstrated by Charnley himself, i.e. mean wear of 0.1 mm/year. From an extensive review of the literature, Clement et al.[27] concluded that there was no evidence in the literature to show that non-cemented acetabula would present better results than cemented acetabula. In their analysis on all ages and indications, they concluded that cemented acetabula continued to be the gold standard. In relation to new materials, Gottliebsen et al.[28] analyzed non-cemented arthroplasty procedures with and without hydroxyapatite and concluded that implants with hydroxyapatite wore out more rapidly, at 0.18 mm/year, versus 0.12 mm/year. Dahl et al.[29] compared cemented prostheses with ceramic heads and with chromium–cobalt heads and observed that the wear rate in the former was 0.05 mm/year and the latter, 0.1 mm/year. Thus, non-cemented polyethylene pieces presented greater wear, which may have been related to their smaller thickness, as also observed in the present study.

Furthermore, determination of the dimensions is also important when a femoral component is exchanged, with placement of a new head. It needs to be asked whether this will really have the same diameter as the old one and thus, whether it will fit perfectly without causing friction and particles. Likewise, it needs to be asked whether an acetabulum of diameter 50 mm, for example, from one company is equal to one of 50 mm from another company. This study showed that not all the heads were compatible, given that although they were around the size desired in the planning, this space presented small variations, which might have been enough for a perfect fit between different brands to be achieved. In the same way, for the cemented components, it was observed that not all the largest diameters (50 mm) were really what was claimed. In a similar study, but on polyethylene pieces for knee arthroplasty, Schwartsmann et al.[30] observed that the thickness of the polyethylene piece was not stated correctly by the manufacturers. These authors observed that the measurements found were smaller than the specifications of each of the manufacturers, and that the imported polymers were not superior to the Brazilian ones regarding thickness. Similar results were observed in the present study, but for acetabula.

In the case of non-cemented components, future studies should take into consideration the acetabulum in the metal dome at the time of measuring the largest diameters. The thicknesses of these polyethylene pieces were smaller than those of the cemented components, which may explain why there was greater osteolysis in the non-cemented arthroplasty procedures. Mall et al.[31] analyzed crosslinked and conventional polyethylene pieces and, after five years of follow-up, found osteolysis in only 2% of the first type but 24% of the second type.

It should be borne in mind that in the present study, we did not discuss the quality of the implants, which is a factor that might explain the generally smaller thickness of the imported components. It could be asked whether this was because the polyethylene was of better quality, or whether this was done as an economy measure in the manufacturing process. Nonetheless, the spaces destined for articulation of the femoral heads seems to present greater standardization, with fewer discrepancies, even though there is incompatibility between brands and models.

Conclusion

This dimensional analysis on the acetabula available on the Brazilian market showed large differences between brands and models. The measurement of a 50 mm acetabulum was rarely found, either in cemented or in non-cemented polyethylene pieces, and either in Brazilian or imported pieces. The non-cemented acetabula had smaller thickness, by around 27.96%. The diameters of non-cemented acetabula were also smaller than those of cemented acetabula, but at the expense of the need for insertion in the metal back.

New studies are needed to investigate all brands, all sizes and all models, and also whether there are any differences between batches from the same company. The quality of the implants and their level of crosslinking were not analyzed in the present study.

Conflicts of interest

The authors declare no conflicts of interest.

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