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Influence of patient-specific target ROM definition on the combined target zone for cup alignment in THA

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Abstract

Definition of target zones for prosthesis alignment is a common method in preoperative planning for THA. Several criteria for calculation of these target zones are discussed in literature and a combined target zone (CTZ) has been defined on the basis of morphological and morphofunctional parameters. Especially the definition of a patient-specific target ROM is important for prediction of postoperative prosthesis´ functionality. Prosthetic impingement can limit movements und thus restrict patients in their activities of daily living. A precise analysis of the postoperative target ROM can help to provide prosthetic impingement during movements, which are essential for the individual patient and also improve the size of the resulting CTZ for prosthesis alignment. We analyzed four different ROM definitions and their impact on the size of the ROM based target zone (ROMTZ) as part of the CTZ on a database of 200 patients. We found significant differences between the sizes of the resulting ROMTZs. Hence, our study underlines the effectiveness of a differentiated evaluation of the individual target ROM for optimized preoperative planning in THA.

1 Introduction

Based on the developments of recent years, an increase in the number of THA patients can also be expected in the future. Furthermore, THA patients tend to be younger and more active, resulting in higher demands and loads on the prosthesis [1]. Against this background, individualized planning will continue to become a focus of research in the field of orthopedic preoperative planning.

Several criteria for THA planning have been developed in the past to minimize dislocation, wear and loosening and thus the need for revision [2,3].

The concept of the patient-specific combined target zone (CTZ) which was previously presented by our group, combines respective criteria. Individual target zones are calculated regarding morphological parameters (MorphTZ), ROM (ROMTZ) and load situation (LoadTZ) and are then merged into one combined target zone for cup alignment [4]. The definition of patient-specific requirements is essential with regard to all three target zones. This includes the individual morphological analysis of the patient, the definition of the load on the prosthesis, but also to fulfil the expectations and thus maximize the satisfaction of the patient. The patient-specific functional requirements in terms of ROM and load are defined by ADL that differ for cultural background of the person, but also for the work situation and sporting activity [5,6]. The definition of an individual ROM based on patient-specific data is therefore an important aspect in the context of preoperative planning.

In this work, ROM definitions from the literature have been compared to exemplary patient-specific ROM definitions from five Caucasian subjects of representative age for primary THA. The influence of the different ROM definitions on the ROMTZ has been investigated.

2 Material & Methods

Different ROM definitions were compared in this analysis. Widmer and Zurfluh define a large ROM (Widmer) by arguing that ROM for impingement analysis has to be larger than the normal ROM [7]. Turley et al. define ROM (Turley) based on a systematic review of the MEDLINE database [8]. In addition, two different exemplary individual ROMs were defined based on questionnaire data from Caucasian people of representative age for primary THA (65.8 ± 4.3). The questionnaire contains 22 different ADLs, whereby some, such as “tying shoes” additionally includes different variations. Five subjects were asked to assess the relevance of the ADLs for their everyday life. Two different ROM definitions (IndROM1 and IndROM2) were built from the relevance assessment of the questionnaire (**Figure1-A).**

For target zone analysis an existing database with pre- and postoperative CT imaging of 200 Japanese patients that underwent primary THA was used. Pelvic and femoral bones were segmented and landmarks were detected as described by Fischer et al. [9]. The bones were rotated in a reference position that is standing position for application of flexion-extension and adduction-abduction and 90 ° flexion for application of internal-external rotation **(Figure 1-B)**.

The ROMTZ was calculated by applying the individual movements required for the different ROM definitions. All cup orientations between 10 ° and 70 ° inclination and – 20 ° and 50 ° anteversion were tested for prosthetic impingement **(Figure 1-C)**.

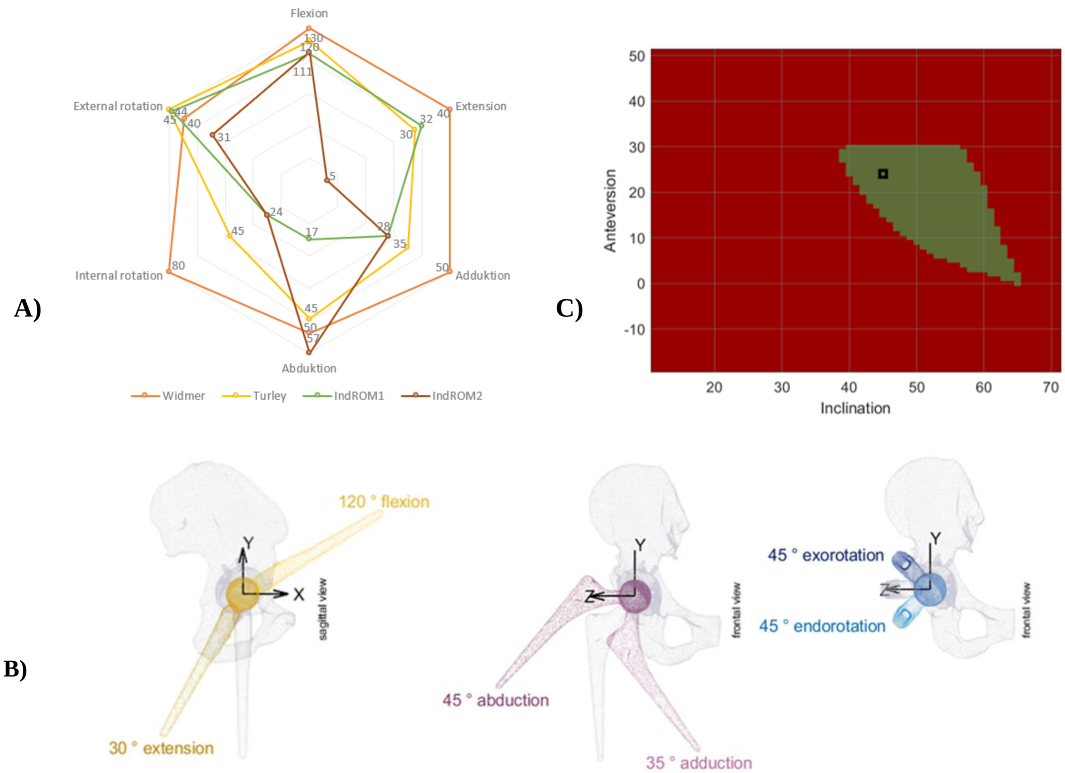

Figure 1: (A) Comparison of ROM definitions; **(B)** Application of Widmer for ROMTZ analysis; **(C)** Exemplary visualization of ROMTZ. The size of the ROMTZ was calculated as target area (green) in percentage of the total area (red and green).

3 Results

Widmer shows the largest movement area. Turley results in an 18 % smaller movement area. For both individual ROMs (IndROM1 and IndROM2) the movement area is 35 % smaller than the one of Widmer, although the values for the individual degrees of freedom showed major variations **(Figure1-A)**.

For Widmer 56 % of patients showed no ROMTZ (in other words: no solution for cup alignment, that enables the whole ROM without impingement), for 3 % of patients the size of the ROMTZ was more than 10 % and no patient had a bigger ROMTZ than 15 %. For Turley for more than 50 % of patients the size of the ROMTZ was at least 10 %. 1% of patients achieved a ROMTZ of at least 30 %.

Although the total movement area of both individual ROMs was the same size, the variations for the individual degrees of freedom led to different sizes of the ROMTZ. For IndRom1 about 75 % of patients showed a ROMTZ of more than 10 % and about 25 % of patients showed a ROMTZ of more than 20 %. IndROM2 led to a ROMTZ of more than 10 % for 90 % of patients and more than 20 % for more than 50 % of patients. 1 % of patients showed a ROMTZ of more than 50 % for IndROM2 (**Table 1**). The differences between the ROMTZs were significant following a Kruskal-Wallis-test ($\alpha = 0.05$).

Table 1: Size of ROMTZ [%] for different ROM definitions

	Widmer	Turley	IndROM1	IndROM2
Size of movement area	100	82	65	65
Mean size of ROMTZ	2 ± 3	11 ± 7	15 ± 8	22 ± 11
ROMTZ = 0 %	56	9	4	1
ROMTZ > 5 %	13	76	87	95
ROMTZ > 10 %	3	54	74	90
ROMTZ > 15 %	0	25	47	78
ROMTZ > 20 %	0	12	24	55
ROMTZ > 30 %	0	1	5	14
ROMTZ > 50 %	0	0	0	1

4 Discussion / Outlook

The calculation of an impingement-free target zone for cup alignment is a highly relevant aspect in preoperative planning for THA that requires the definition of a desired target ROM [10,11,12].

With this work, we analysed the size of the ROMTZ for four different ROM definitions. We found major differences in the ROM definitions, as well as in the size of the resulting ROMTZ. Note, that a larger ROMTZ provides a higher tolerance or more options for cup-alignment respectively. In addition, the consideration of further patient specific constraints induced by morphologic boundary conditions (MorphTZ), the load situation (LoadTZ) and its superposition in the combined target zone (CTZ) further decrease the tolerable area for optimal cup alignment (see [4]), thus increasing probability of suboptimal therapeutic outcome. Therefore, our work underlines the need for accurate determination of the individually desirable target ROM to optimize implant positioning and thus surgery result.

Further investigations regarding a precise definition of the target ROM based on preoperative information are desirable. As the change in cup alignment has no influence on the position of the bones, bony impingement, that is also part of the CTZ calculation, was not taken into account in this study. Further investigations regarding stem position and bony impingement complement the present study and can contribute to a comprehensive assessment of the prosthesis´ functionality. An optimized preoperative planning that takes the individual needs and requirements of a patient into account can reduce a patient´s impairments caused by the prosthesis and thus increase patient satisfaction.

5 References

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